VOLUME VI. NUMBER 3

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

EDITOR

C. A. CHANT
University of Toronto, Toronto

ASSOCIATE EDITORS

W. F. KING
Chief Astronomer
Ottawa

R. F. STUPART
Director of the Meteorological Service of Canada, Toronto

J. S. PLASKETT
Dominion Observatory
Ottawa

PUBLISHED BI-MONTHLY

MAY-JUNE, 1912

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.
FOREIGN AGENTS: WILLIAM WESLEY & SON,
28 ESSEX ST., STRAND, LONDON.

THE JOURNAL

OF THE

ROYAL ASTRONOMICAL SOCIETY

OF CANADA

VOL. VI. MAY-JUNE, 1912. No. 3

Precise Levelling in Canada	*F. B. Reid*	151
A Long-Period Spectroscopic Binary	*W. E. Harper*	179
Orbit of ξ Persei from the H and K Lines	*J. B. Cannon*	188
Meetings of the Society		
At Toronto	*L. G.*	197
At Ottawa	*C. E.*	198
At Hamilton	*T. H. W.*	200
At Peterborough	*D. B. M.*	200
At Guelph	*J. T. L.*	202
Notes from the Meteorological Service		
Report of the Weather in Canada, April-May	*R. F. S.*	203
Earthquake Records at Toronto and at Victoria, B. C.	*J. V.*	207
Magnetic Observations	*R. F. S.*	210
Astronomical Notes		
A Note on Gelatine used in the Making of Light-Filters		211
The Solar Eclipse of April 17		212
The Great Telescope for the Allegheny Observatory		213
Magnetic Power of the Earth		214
Value of Scientific Research		214
Convergent Stars	*J. K. C.*	215
Notes and Queries	*C. A. C.*	216

Editorial communications should be addressed to C. A. Chant, University of Toronto, Toronto, Ont.

Business correspondence, remittances, etc., should be addressed to Chas. P. Sparling, Treasurer of the Society, 198 College Street, Toronto.

Communications regarding Library matters should be addressed to the Librarian.

$2.00 per annum. Single numbers, 35 cents.

Subscription to the *Journal* is included in membership fee.

Anyone wishing to purchase a Telescope may correspond with the Secretary, Toronto.

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

OFFICERS FOR 1912

Honorary President—W. F. KING, C.M.G., LL.D., Chief Astronomer, Ottawa.
President—Professor LOUIS B. STEWART.
First Vice-President—J. S. PLASKETT, B.A.
Second Vice-President—A. D. Watson, M.D.
Secretary—J. R. COLLINS. *Treasurer*—CHAS. P. SPARLING.
Recorder—LACHLAN GILCHRIST, M.A. *Librarian*—Dr. W. M. WUNDER.
Curator—ROBERT S. DUNCAN.

Council—The above Officers, and the following members:—G. PARRY JENKINS, F.R.A.S., Toronto; Rev. I. J. KAVANAGH, S.J., D.Sc., Montreal; Rev. Dr. MARSH, F.R.A.S., Peterboro; A. F. MILLER, Toronto; Sir JOSEPH POPE, K.C.M.G., Ottawa; R. M. STEWART, M.A., Ottawa; and Past Presidents ANDREW ELVINS, JOHN A. PATERSON, K.C., M.A.; R. F. STUPART, F.R.S.C.; Professor C. A. CHANT, W. BALFOUR MUSSON, Professor A. T. DELURY; and the presiding officer of each Centre as follows: J. S. PLASKETT, B.A.; H. O. FISKE, C.E.; WM. BRUCE, J.P.; N. MACMURCHY, B.A.; Professor N. B. MCLEAN and HENRY WESTOBY, Esq.

OTTAWA CENTRE

Local President—J. S. PLASKETT, B.A.
Vice-President—R. M. STEWART, M.A.
Secretary—CARL ENGLER, B.A. *Treasurer*—C. C. SMITH, B.A.
Council—W. E. HARPER, B.A.; F. A. MCDIARMID, B.A.; R. E. DELURY.

PETERBOROUGH CENTRE

Local President—H. O. FISKE, C.E. *Vice President*—T. A. S. HAY, C.E.
Secretary-Treasurer—REV. D. B. MARSH, D.Sc., F.R.A.S.
Curator—H. O. FISKE, C.E. *Librarian*—T. A. S. HAY, C.E.
Auditor—FRANK ADAMS
Council—A. J. SEGER, D. WALKER, B.A.; T. ELLIOTT, H. CARVETH, S. J. KEYES, A. J. JOHNSTON, PHM.B.; D. E. EASON, B.A.Sc.

HAMILTON CENTRE

Local President—WM. BRUCE, J.P.
First Vice-President—E. H. DARLING, A.M.C.S., C.E.
Second Vice-President—W. A. ROBINSON.
Secretary—T. H. WINGHAM, B.A. Sc. *Treasurer*—SENECA JONES.
Council—REV. R. E. M. BRADY, D.Sc.; REV. J. J. MORTON, G. PARRY JENKINS, F.R.A.S.

REGINA CENTRE

Hon. President—WM. TRANT. *Hon. Vice-President*—P. MCARA, Jr.
President—N. MACMURCHY, B.A.
First Vice-President—H. LANG. *Second Vice-President*—MRS. J. F. BRYANT.
Secretary—H. S. MCCLUNG. *Treasurer*—J. F. BRYANT
Council—C. B. KEENLEYSIDE, J. E. DOERR, Miss E. D. CATHRO.

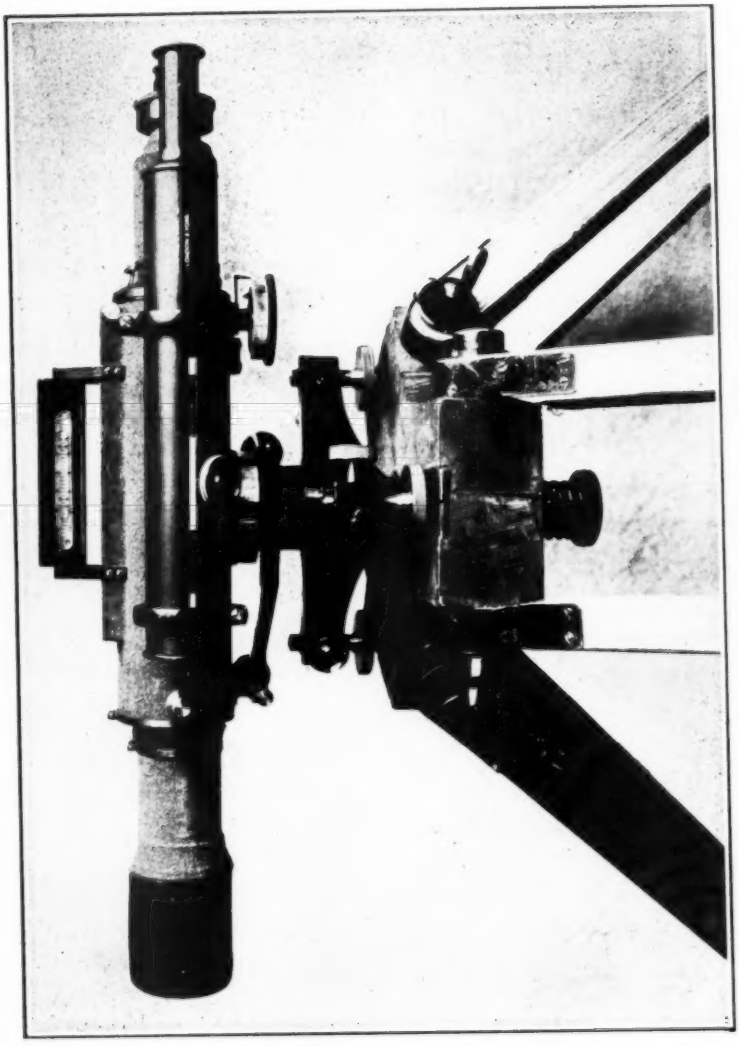
WINNIPEG CENTRE

President—PROFESSOR NEIL B. MACLEAN.
Vice-President—
Secretary-Treasurer—C. E. BASTIN.
Council—MRS. L. B. IRELAND, H. C. HOWARD, R. E. COLLINS, REV. FATHER J. BLAIN, S.J.; MRS. KEMP.

GUELPH CENTRE

Honorary President—COLONEL A. H. MACDONALD, K.C.
Honorary Vice-President—DR. W. F. SAVAGE.
President—HENRY WESTOBY, Esq.
First Vice-President—PROFESSOR W. H. DAY, B.A.
Second Vice-President—DR. J. LINDSAY. *Secretary*—H. E. S. ASBURY.
Recorder—J. T. LUTON. *Treasurer*—H. J. B. LEADLAY.
Council—DR. A. H. HOBBS, REV. W. J. WILSON, W. C. MCLAREN, W. TYTLER, MRS. H. J. B. LEADLAY AND MRS. W. O. STEWART.

PRECISE LEVELLING ROD



PRECISE LEVELLING INSTRUMENT

THE JOURNAL
OF THE
ROYAL ASTRONOMICAL SOCIETY
OF CANADA

VOL. VI. MAY JUNE, 1912. No. 3

PRECISE LEVELLING IN CANADA

BY F. B. REID

WHILE this paper has the rather comprehensive title of "Precise Levelling in Canada" it should be explained at the outset that it has special reference to the methods employed and the territory covered by the Geodetic Survey, and it is intended merely to touch upon the work of other branches of the Government Service along these lines. In this country, the only precise levelling of any extent, so far as I am aware, is that which has been carried out by the Government, though in the United States some of the railways, notably the Baltimore and Ohio and the Pennsylvania Railroad, have undertaken precise level lines of considerable extent on their own account.

This fact, namely, that some of the leading American Railroads have gone to the expense of running precise levels for their own benefit, does much to prove the demand for levels of a high degree of accuracy; also, I might say, that while the work has been carried on for only a comparatively short time in Canada — the first work by this Department was done in 1906— and is, therefore, not very widely known, yet we have had a large number of enquiries for the results, from railway corpora-

tions, city engineers, surveyors, consulting engineers and others. While the work is of great use to the public at large it is of equal importance to the Geodetic Survey in the extension of its system of triangulation, and to the various topographical surveys carried on by the Militia and other Government Departments; also to the International Boundary Survey. The making of accurate contour maps of any country is very greatly facilitated by a line or a net of precise levels.

If any further proof were needed for the necessity of this work a perusal of White's Dictionary of "Altitudes in the Dominion of Canada" would furnish a good deal of it. This is a very comprehensive work and has been prepared with great care from the best available information, obtained from many sources. In its preparation, however, many very large discrepancies in the elevations of junction points of railways, etc., were discovered, which it was found impossible to overcome by the use of the information at hand. I will instance three or four cases on the main line of the Canadian Pacific Railway from Vancouver to St. John, N.B. The elevation published for Donald, B.C., by levels from the Pacific Ocean is 2586 feet above sea level, and by levels from Lake Superior, 2574, a discrepancy of 12 feet. At Cartier, the first divisional point west of North Bay, there is a similar discrepancy of 34 feet between the levels from Lake Superior and from Montreal. At two points on the line through the State of Maine, also, there are discrepancies, one of 18 feet and one of 7 feet. These discrepancies all have the same sign and, therefore accumulate in the same direction, to the total amount of 71 feet. While there may be a slight difference in elevation between the Atlantic and Pacific Oceans along the respective coast lines, it would certainly amount to but a small fraction of this difference, and an investigation by means of precise levelling would seem to be in order.

Precise levelling is, whenever possible, carried along railway tracks, rather than along highways or across country, the advantages of this practice being many. The rate of rise and fall of the track is usually fairly uniform and no steep hills are

encountered, thus allowing longer average sights to be taken and allowing the backsights and foresights to be easily kept of equal length. The rails furnish excellent supports for the levelling rods and thus the time is saved which would otherwise be consumed in putting artificial turning points into the ground. The masonry structures — bridges and culverts — situated along the railways are utilised for placing permanent bench marks; this is of great advantage both to us and the railway companies. Again, the use of a hand-car for going to and from work and for moving along from point to point during the day effects a great saving of time and labor, and the transportation of the camping outfit from camp to camp by freight is cheaper and more convenient than the method by horse and wagon. Against these and many other advantages may be set the fact that the refraction and boiling of the atmosphere in the heat of the bare ballast and rails of a track is worse than on a highway. Dodging fast trains coming through rock cuts and around curves, lends a spice of danger and excitement to the work which would not be found on a country highway.

The levels of the Geodetic Survey in Ontario and Quebec have been started from a bench mark established by the United States Coast and Geodetic Survey at Rouse Point, N.Y. This bench mark is included in an elaborate net of precise levels and water transfers which are based on mean sea level at New York and its adjusted elevation is believed to be very close to the truth. At any rate it is the best available datum at present; eventually the Geodetic Survey may have a mean sea level datum of its own, but this is something which requires several years of gaugings to determine accurately.

From Rouse Point two lines of levels have been extended, one westerly through Lacolle Junction, Coteau Junction, St. Polycarpe Junction, Kempton, Prescott, Hamilton, London and Chatham to Windsor, with a branch from Hamilton to St. Catharines and Bridgburg; the other line easterly through St. Johns and Sherbrooke to the International Boundary 15 miles east of Megantic, Que.; branches have been extended from this

line to the International Boundary from Farnham, Foster, Sherbrooke and Lennoxville, and from Megantic to the St. Lawrence River at Levis via the Quebec Central Railway. A considerable amount of levelling has been done in New Brunswick and Nova Scotia ; starting from the town of St. Stephen, a line has been extended northerly to the St. Lawrence River at Rivière du Loup, this line runs for most of its length within a short distance of the border of the State of Maine and branches have been connected at intervals so as to furnish accurate levels for the International Boundary Survey, Easterly from St. Stephen the line has been extended through St. John and Moncton and through Nova Scotia as far east as Mulgrave, on the Strait of Canso.

All the elevations in the Maritime Provinces are based — provisionally — on a bench mark at St. Stephen, N.B., established by the United States Corps of Engineers ; connections have been made at Rivière du Loup and Moncton with the precise levels of the Public Works Department of Canada which have been carried from Montreal to Halifax via the Intercolonial Railway ; these levels are connected with the Rouse Point bench mark and also with mean sea level at Halifax. The fact that our levels agree very closely with theirs goes to show that the St. Stephen bench mark is very nearly correct and that the elevations of our bench marks throughout the Maritime Provinces are very close to the truth and of far greater accuracy than is necessary for ordinary engineering and surveying purposes. Last summer a start was made at levelling along the Grand Trunk Pacific Railway from its junction with the Quebec Central Railway on the Megantic-Levis line to the town of Edmundston, N.B., on the St. Stephen–Rivière du Loup line, a distance of some 230 miles through a very rough country. It is hoped that this link may be finished during the present season and then all the bench marks in the Maritime Provinces may be corrected by a small, constant quantity, which will reduce them to the same datum as those throughout Ontario and Quebec, and will form one net of levelling extending from the Maritime Provinces to Western Ontario.

In Western Ontario, two circuits, composed entirely of our own levelling, have been completed, and the excellent results — shown by the small closing error — are a source of great satisfaction. As mentioned above, a main line of levels extends from Toronto to Windsor, along the Grand Trunk Railway through Hamilton, London and Chatham; a branch line leaves this at Toronto and extends along the Canadian Pacific Railway to Owen Sound, thence southerly along the Grand Trunk Railway through Palmerston, Listowel and Wingham to a connection with the main line at Hyde Park Junction, 4 miles west of London. Another line leaves the Owen Sound-Hyde Park line at Lucan Crossing, 15 miles north of Hyde Park Junction, and extends through Sarnia to Chatham, where a second connection is made with the main line. The new elevation found for the bench mark at Hyde Park Junction is 0·15 feet higher than the original elevation, and at Chatham 0·11 feet lower than the original. The length of the Toronto-Hyde Park circuit is about 436 miles and the length of the Toronto-Chatham circuit about 595 miles so it may easily be seen that the levelling shows a high degree of precision in actual practice.

In the spring of 1910 levelling was inaugurated in the Western Provinces. To secure a sea level datum for this work it was found necessary to go to the town of Stephen, Minn., about 45 miles south of the International Boundary at Emerson, Man. The precise levels of the United States Coast and Geodetic Survey having been extended to this point, furnished what was desired. It was necessary to carry the levels through United States territory to the International Boundary at Emerson, the boundary was then followed to Gretna, a few miles west, and the railways parallelling the boundary followed westerly from that point. As in the case of the Maine and Vermont boundaries, so here, branch lines have been run at convenient intervals for the benefit of the International Boundary Survey. The levelling, at the close of last season, had reached the village of Frobisher, Sask., about 27 miles east of Estevan, on the Canadian Pacific Railway

Returning to Ontario, the programme for the present season, includes running from Bolton on the Toronto–Owen Sound line, towards Sudbury via C.P.R., and it is hoped that this line will eventually be extended west to connect with the line mentioned above as running west from Emerson; this will, however, be the work of several years owing to the great distance involved.

From a consideration of the various routes outlined above, it will be seen that the general policy has been to extend main trunk lines of levels throughout the country at first, putting in branches where necessary for the immediate use of the Boundary Surveys or other public works; as these lines are completed duplicate lines may be run and circuits of levelling closed. In selecting routes between terminal points it has been usual to follow the line which passes through the best settled country and includes the greater number of towns and cities; though in a few cases this policy has been departed from in order to connect with outside bench marks or to avoid parallelling work which has been done by the Public Works Department, as in the case of the line between Coteau Junction, Que., and Prescott, Ont.; that Department had levelled from Coteau to Cornwall, consequently, to avoid duplication, the levels of the Geodetic Survey were carried around by St. Polycarpe and Kempton, an extra distance of about 19 miles.

The Public Works Department has conducted precise levelling at intervals since 1883. During the years 1904-05-06 a long line of levels, starting from the Rouse Point bench mark, was extended through Ottawa and Pembroke to North Bay, for use in the extensive surveys undertaken by the Department for the purpose of locating and determining the cost of the projected Georgian Bay Ship Canal; this line was checked by a line from Toronto to North Bay, starting from a bench mark at Toronto which had been established by means of water transfers from Tibbett's Point, N.Y., at the eastern end of Lake Ontario.

Precise levelling was carried on by the International Boundary Survey in connection with the survey of the 141st meridian,

the boundary between Canada and Alaska, in 1908-09-10. Starting from White Pass, B.C., levels were carried along the White Pass and Yukon Railway to White Horse and thence by wagon road to Dawson and over the glacier trail to the 141st meridian; the total distance levelled was in the neighborhood of 500 miles, but this distance does not give a proper idea of the amount of labor involved, owing to the fact that most of the work was not on a railway track but on rough trails through an uncivilized country.

The instruments and methods employed on this work were practically the same as those in use by the Geodetic Survey, modified when necessary to suit the different conditions under which the levelling was performed.

BENCH MARKS

In the foregoing, mention has been made of the bench marks established: it will now be in order to say something of the nature of these — the only permanent field records of the work performed.

The standard bench mark established by the Geodetic Survey, previous to the year 1908 consists of a copper bolt ½ inch in diameter and 4 inches long, stamped on the end with the letters "B. M., D. A. O." (Bench Mark, Dominion Astronomical Observatory). During 1908 and since then the standard bench mark has been a copper bolt ¾ inch in diameter and 4 inches long, stamped on the end with the letters "G. S. C., B. M." (Geodetic Survey of Canada, Bench Mark). In either case the bolt is sunk horizontally in rock or masonry, a hole being drilled of the exact size of the bolt or a shade larger and the latter hammered in till it completely fills the hole, the end being flush with the surface of the masonry or projecting slightly; properly put in, it is impossible for anyone to remove it without destroying the surrounding rock or masonry. After the exposed end has been planed to a smooth surface by means of a file it is stamped with a steel die containing the above mentioned letters; then a horizontal cross mark is made with a cold chisel, upon

which the elevation is taken ; finally a number is stamped with other steel dies. The question is often asked " Why do you not indicate the elevation of the bench mark also ? " In reply to this I would say that the elevation of a bench mark in a precise levelling net may never be finally determined ; the closing of circuits and introduction of new cross lines will always call for adjustments which will make changes of greater or less magnitude in the elevations ; it would, therefore, be impossible to place more than an approximate figure upon it. Also the computation of the elevations from the field notes is a work of some magnitude and would delay the operations of the parties were it performed in the field, and is, therefore, left to be done in the office after the notes have all been carefully checked. I might say also that an engineer would not usually attempt to look for the bench marks haphazard, but would secure descriptions of their locations ; when getting these, the elevations can always be secured at the same time without difficulty. Bench marks are placed in the stone and concrete structures along the railways, sometimes in large boulders and in rock cuts, and when towns or cities are situated within a reasonable distance of the line, branch lines are run to them and bench marks placed in public buildings such as post offices, court houses and churches. Levellers are instructed to place bench marks at distances of three miles apart, or less. It has been found impossible, however, in many cases, to secure good locations for bench marks at anything like this distance apart, so the expedient was adopted by us in Manitoba in 1910, and in this part of the country in 1911, of building concrete piers, specially for bench marks.

These piers are 6 feet 3 inches high, 9 inches square at the top and 15 inches squares at the bottom, resting on a 6 inch concrete footing ; the whole pier is buried to within about 9 inches of the top and the copper plug built in, near the ground surface, having been previously stamped and numbered. The piers are usually built on the railway right-of-way, within 3 or 4 feet of one of the fences and on fairly level ground, where they will not be exposed to danger from future alterations in the railway

grade. The concrete consists of a mixture of one part cement, two parts sand and five parts gravel ; the latter ingredients can often be secured by sifting the ballast on the track. Portable wooden forms are employed .which can be removed after the concrete has set and used over again ; the total time consumed building a pier, including the excavating, removing the forms and back-filling, averages between one-half day and one day, probably nearer the latter.

The piers are not built at any definite distance apart ; it is left to the discretion of the leveller to put them in where they appear to be necessary.

Temporary bench marks are placed at intervals of 1 mile or thereabouts, they consist usually of spikes, driven horizontally into telegraph poles, and, as their designation implies, they are used only for convenience while the work is progressing ; they are not embodied in the final office records.

The permanent bench marks above described are neat and unobtrusive, not likely to be discovered and defaced by unauthorized persons, but easily found by anyone furnished with a description, and are, therefore, well adapted for use in a settled country like that in which most of the work of the Geodetic Survey has been carried on.

For use along the Alaska Boundary, however, they were not considered suitable, owing to the absence of masonry structures and for other reasons, so a different form of bench mark was employed, being a circular copper plate 4 inches in diameter with a stem at right angles to the plate and about 3 inches long; the plate was placed flat on top of a surface of rock, the stem being solidly cemented into a hole drilled for that purpose ; the elevation was taken on top of a knob at the centre of the plate. When suitable rock could not be found the copper plate was set on the top of an iron post which was firmly planted in the ground, projecting a short distance above the surface. Bench marks were put in at distances of 10 miles or thereabouts.

The bench mark used by the Public Works Department is similar in form to that of the Geodetic Survey, but contains no

mark on its exposed surface but the cross mark upon which the elevation is taken, the number of the bench mark is cut in large Roman numerals upon the masonry adjoining it.

INSTRUMENTS

The instrument adopted is a precise level very similar in design to that used by the United States Coast and Geodetic Survey. It may be described as a modification of the engineer's Dumpy level, in that the telescope is firmly attached to its supports and is not removable as in a wye level. The materials used are nickel-iron, an alloy consisting of 36 parts nickel and 64 parts iron and nickel steel (or Invar) an alloy of the same proportions of nickel and steel. The latter alloy is used for the mountings of the level vial, for the collars, diaphragms, adjusting screws and any other parts required to retain their relative position as nearly as possible. The co-efficient of expansion of these alloys — especially nickel-steel — is exceedingly small.

The instrument base is a single piece of hard and finely grained cast iron and is supported by the three levelling screws. The instrument centre is of unusual length and passes down through a hole in the tripod head, thus allowing the telescope to rest low down — near the tripod — and giving greater stability to the instrument when used in a wind. The telescope itself is completely enclosed in an outer tube in which it is allowed a small motion vertically; it is supported at the object glass end by a horizontal pivot and at the other end rests on the point of a fine micrometer screw by means of which it may be raised or lowered by an exceedingly small amount. When the instrument is not in actual use and is being carried from station to station the telescope tube is lifted from the point of the micrometer screw by means of a small lever; this keeps the telescope pressed tightly against the upper part of the casing and saves the point of the screw from wear. At the lower end of the screw a drum or micrometer head, subdivided by a hundred graduations, is provided. The upper part of the outer casing has cast into it a rectangular opening with a framing surrounding it; a piece of

plate glass, fitted into this framing in grooves closes the opening against dust or air currents, but can be quickly removed, when necessary, for the purpose of adjusting the level. The tube containing the level vial is set within this opening, as close to the line of collimation as possible. This position of the vial has the advantage of protecting it, to a large degree, from sudden changes of temperature. A small rectangular mirror placed above and parallel to the level tube, reflects the bubble into two prisms placed in a tube immediately to the left of the telescope tube. By this means the observer is enabled to watch the action of the bubble with his left eye while reading the rod with his right eye ; that is, he can transfer his attention instantaneously from the one to the other. The level vial is constructed with a small chamber at one end communicating with the body of the vial by an opening at the edge of the tube ; by tilting the instrument so as to raise one end of the vial the spirit can be caused to run to or from the chamber ; in this way the length of bubble used may be kept constant throughout the varying temperatures of the day or the season. This adds to the refinement of the work, as the grinding of the vial is more accurate near the centre and it is consequently not well to allow the bubble to lengthen out too much. One division on the level vial has a value of about 2½ seconds of arc.

Three cross wires of fine spider web are placed in the diaphragm, in order that three readings of the rod may be made at each observation. Two eye-pieces, of different powers of magnification, are provided ; the high power to be used under ordinary atmospheric conditions, and the low power when the trembling and boiling of the atmosphere, due to heat waves, is unusually severe.

Great care has been expended on the construction of the rods used upon this work. They are built up of separate pieces of white pine giving a cross section in the form of a symmetrical cross so as to prevent bending and warping ; they are boiled thoroughly in paraffin which tends to keep them of constant length under varying conditions of atmosphere and temperture.

Silver plugs are inserted in the face of the rod approximately at the three, six and nine foot points and the exact position of these points marked by a fine scratch on the face of the plug; the rod is then subdivided into feet, tenths and hundredths in alternate white and black spaces of one one-hundredth of a foot. When observing the rod the readings are made to thousandths, the hundredth spaces being subdivided by estimation. As it is impossible to subdivide a black space accurately at the distance the rod is usually observed, two sets of graduations are placed, side by side, one on each side of the centre line of the rod, the white spaces of one adjoining the black spaces of the other; thus the observer has always a white space to subdivide by reading on the right hand or the left hand set of graduation marks, as the case may be. The bottom of the rod is formed of a cast steel foot block with a hemispherical knob on the bottom, suitable for holding on flat surfaces.

Another piece of apparatus which can hardly be classed under the heading of instruments, but which is very necessary nevertheless, is a large carriage umbrella with a handle about 8 feet long, provided with a spike at the end to insert in the ground. The umbrella is used whenever the sun is shining while observations are in progress to shade the instrument from its rays; without this the parts would become unequally heated and irregular and unreliable action of the bubble would follow.

While carrying the instrument between sights a cover of duck or cravenette is used for the same purpose, this also is used to protect it when working during a light rain; in a heavy rain the work has been discontinued.

FIELD OPERATIONS

A precise levelling party consists of seven men, the observer, the recorder, umbrella man, two rod men, cook and a railway man, usually a section man or brakesman, to pilot the hand-car. Camps are made at the stations along the line, the distance apart of camps varying from ten to twenty miles according to the locations of towns and villages and to the condition of the inter-

vening track as to grades. The levelling is carried continuously forward, day by day, through the camp and to a point about half way to where the next camp ahead will be ; permanent and temporary bench marks being put in so as to divide the line into sections of one mile or less. From this point, backward levelling is commenced and carried along to the point where the line was taken up, probably about half way from the previous camp, all bench marks being checked upon on the backward run.

I will quote from the general instructions issued to levellers: — "All lines are to be levelled twice, in opposite directions, called forward and backward levelling. Backward shall in every respect be independent of forward levelling and the same turning points shall not be used. If the forward levelling is made in the forenoon, the backward — over the same section — should be made in the afternoon. In this respect the opposite conditions as to intensity of light are desirable, but the work must not be delayed for this purpose. . . . . When a discrepancy in the thread intervals, or any other error is discovered, even although the nature of the error may appear to be self-evident, the section involved must be re-levelled from the preceding bench mark, and the word "cancelled" written across the pages of the level book containing the reading along the discarded section. The word "re-levelling" should be written at the tops of all pages recording the new readings.

"The field books shall in every respect be self-evident records of the work on the ground. The difference of elevation, as indicated by forward and backward levelling — between two permanent bench marks — shall correspond within $0'{\cdot}017\sqrt{M}$, M" being the distance in miles between the benches.

"If the difference between a forward and a backward levelling is greater than allowed, the section shall be levelled anew, both forward and backward, until two measures within the limit of error are secured. In this way four, six or more measures are made, the mean of all being taken and the individual residuals determined. Reject all those results whose residuals are

greater than 0'·015 ; then take a mean of the remaining measures for a final result."

This requirement that the discrepancy shall be within 0'·017 ✓distance in miles has been adhered to as closely as possible throughout the work ; this means that for 1 mile the forward and backward shall correspond within 0'·017, for 4 miles within 0'·034, for 100 miles with 0'·170 and so on. Quite frequently the total discrepancy of a line shows a constant, and often unaccountable tendency to accumulate in one direction. Various precautions are used to guard against this. If, when reading from the successive instrument stations, or set up points, the rear rod were always read first, and the forward rod last, any settlement of the level between the backsight and foresight would have a constant tendency to make the foresights too small in comparison with the backsights, and on the backward levelling this effect would be repeated, causing the discrepancy to accumulate rapidly ; this is obviated by reading on the rear rod first at one station and on the forward rod first at the next station so that any settlement at one will be counteracted by the settlement at the next ; this method also has the advantage of eliminating the effect of a uniformly changing refraction in the atmosphere, such as usually occurs most noticeably in the early morning and late afternoon hours. It, of course, has the effect of holding back the progress of the work considerably, as at every second set up the leveller has to wait for the front rod man to reach his turning point, and afterwards wait for the rear rod man to overtake him before going forward (these remarks are intended to apply where the levelling is carried along a railway track and a hand-car used between sights). However, in precise levelling accuracy is the first consideration and speed is secondary.

Another source of error would be a systematic rising or settling of the rod supports, this would have a similar effect to the movement of the level, and cannot be guarded against in the same way, so it is essential that rod supports should be as solid and immovable as possible ; luckily, in running along a railway

the most solid supports are also the most convenient, namely the top of the rails. The rod man holds the rod with its semi-circular knob on a cross made on top of the rail about one foot from the joint; this has been found by all levellers, I think, to be more satisfactory for a turning point than anything else; upon a track in ordinary condition the passage of a train appears to have no effect, the rail may rise and fall an inch or more under the passage of the wheels, but careful comparison of the elevation of the point with some solid point to one side, before and after a train has passed, shows that the rail returns to precisely the same elevation. Of course when the track has been freshly ballasted and is consequently likely to settle under a train, a turning point is taken to one side when a train is known to be approaching. When following a highway, as when running branch lines into a town, suitable steel pins, driven solidly into the ground, are used. The verticality of the rod whilst readings are in progress, is maintained by means of a small spirit level. With regard to rod supports I will quote from the 1907 report of Mr. J. F. Hayford, Inspector of Geodetic Work of the United States Coast and Geodetic Survey. He says:—"In August, 1903, the experiment was made of using a point marked on the top of the rail of the railroad track as the rod support. The most prominent effect was to change the rate of accumulation of discrepancy between the forward and backward lines. This is a clear confirmation of the theory that the accumulated discrepancy is due mainly to a systematic rising or settling of the rod supports. This theory is based upon the frequently observed fact that when a change is made in the method of rod support or in the habits of the rod man, a change is liable to take place in the rate of accumulation of discrepancy between the forward and backward lines.

"The evidence showed clearly that the use of the rail for the rod support increased both the speed and accuracy of the levelling, and the practice has been adopted in all Coast and Geodetic Survey levelling since that time.

"Two uncertainties in connection with the method of rod

support will occur to anyone who considers it carefully, namely, the uncertainty as to whether the rod man holds the foot of the rod for both foresight and backsight on precisely the same point on the slightly rounding and sometimes inclined surface of the top of the rail, and the uncertainty as to the recovery by the rail of its former elevation after a train has passed over it.

"The first of these uncertainties is very small provided the rod man is careful. No difficulty was found in marking the exact spot on the rail which was used in such a way, with chalk or keel, that the mark was recoverable, even after a train had passed over it.

"Direct observations have indicated that, as a rule, the rail rises to sensibly its former elevation quickly after a train passes. Doubtless there are exceptional cases. The best proof available that such cases are comparatively rare for the conditions under which the rail was used as a rod support, and that the systematic permanent settling of the rail was caused by the passage of a train is exceedingly small, is furnished by the comparison given in Appendix 6 — Report for 1904 — of the accuracy of the levelling by each party before and after beginning the use of the rail as a rod support, and this has been confirmed by the good results obtained on later lines."

When a reading is to be made upon a permanent bench mark a chisel about one foot long and one inch wide, bevelled to a flat edge at one end, is inserted in the cross mark in the end of the copper bolt, with the sharp edge at the top, that is, the upper surface of the chisel and the cross mark lie in the same horizontal plane, one man holds this chisel steady and maintains its horizontality by means of a hand level while the rod man rests the rod upon the top of it the same as he would upon the rail.

Foresights and backsights of approximately equal length are used, so as to counteract the effects of refractions and curvature, and of a possible lack of adjustment of the level; this equality is secured by having the rod man count the number of rails from the last turning point to the instrument and from the

instrument to the next turning point ; the instructions are that backsights and foresights should differ by not more than thirty feet.

At this point it will be necessary to say something about the programme of observation followed in the field. The observer sets up the instrument, levels it — as nearly as may be — by means of the three levelling screws, then points it on one or other of the rods and moves the object glass slide in or out till perfect definition of the rod is obtained, he then turns the drum of the micrometer screw which is under the eye end of the telescope to the left or right, as may be necessary, to bring the bubble exactly to the centre of its run, watching it carefully all the while with his left eye. He then makes the three rod readings corresponding to the three cross wires as rapidly as possible, consistent with accuracy, still being careful to see that the bubble maintains its exact centre position ; these readings are recorded by the recorder and the thread interval between the first and second and between the second and third obtained by subtraction ; if these do not correspond within a certain limit — fixed for the particular instrument at the beginning of the season by careful observation under the best conditions — the readings are repeated until they do correspond ; the mean of the three readings is used to ascertain the differences of level ; the use of three readings usually shows up any mistake in reading feet or tenths which might be made in a single reading. The thread intervals obtained as above evidently will correspond to the length of sight, or in other words, the stadia method of obtaining distances is used ; in a column headed "Sum of Intervals" these thread intervals are summed continuously from a bench mark, on the left hand page for the backsights and on the right hand for the foresights, this furnishes a ready means of equalizing the sights, if from any cause, they should become uneven, by setting the level behind or ahead — as the case may be — of the centre point between the rods ; thus at the end of a section the total backsights and foresights may be made as nearly equal as desired.

When running up steep grades, the point read on the forward rod is much nearer the ground than that on rear rod, consequently the effect of refraction, or boiling of the atmosphere, is to distort the foresight more than the backsight; by taking very short sights and thus keeping the line of sight away from the ground as much as possible, the effect is minimized but not by any means eliminated. The only way of doing the latter would be to wait for cool cloudy weather when there is no perceptible refraction. If one makes the forward levelling in such weather and the backward in a bright hot sun or vice versa the discrepancy is usually very noticeable; if both measures were made under the unfavorable conditions the results would show a good accordance, but both would be in error; however, the error would be compensated for on the next down grade, provided the conditions were the same, so in the aggregate effect upon a line I think this class of error should not be classed as cumulative, the more so as in observing during a large number of days one will probably encounter good weather and bad weather combinations indiscriminately upon forward and backward running and upon up and down grades. My own experience has been that the grades have little effect as to causing the total discrepancy to accumulate. Atmospheric refraction affects the readings on the levelling rods most noticeably in two ways:— Firstly, when the ground is being rapidly heated by the rays of the rising sun, the lowest stratum of air becomes in its turn heated by the ground and begins to flow upward; this has the effect of making the readings appear to rise and fall vertically, and even to remain for a minute or so in quite abnormal positions; such conditions are unsuitable for observations; secondly, when the air is bubbling the graduations on the rods appear to dance or vibrate; they are then difficult to subdivide, but no systematic error is to be feared.

The length of sight taken depends upon the atmospheric conditions; under the influence of a bright sun, without any breeze, especially when following a cold night, the boiling of the atmosphere is so severe that the divisions on the rod often

cannot be subdivided with the proper degree of accuracy at a greater distance than 200 feet. Under average conditions sights vary from 300 to 360 feet; on a very favorable day these may be lengthened to 500 or 550 feet or even more; with one of our instruments having a particularly good object glass, sights of over 700 feet have been obtained. The observer is left to use his judgment as to the length of sight he shall use; if he attempts to read farther than he should, the thread intervals will become irregular and time will be lost in taking readings over; in any case the gain in speed in taking sights of over 450 feet or thereabouts is not very marked owing to the time lost in waiting for the rod men to catch up.

The above remarks apply, naturally, to a level or almost level track; on a two per cent. grade, sights of 200 feet could not safely be exceeded in the best of weather.

Owing to these varying conditions it is very hard to say what constitutes an average full day's work; probably it varies for an experienced leveller between seven and eight miles levelled, that is, in one direction only. In the course of a month, a few days and parts of days are lost from high winds and rain, and re-levelling and other causes of delay reduce the total mileage, so that about 65 miles of completed line (levelled both forward and backward) is considered good progress.* These are supposed to be average conditions and are greatly exceeded sometimes under exceptionally good conditions, over 12 miles have been done in a single day, and in one month 87 miles of levelling were completed.

The amount of re-levelling required should not amount to more than 10 or 15 per cent. provided weather conditions are at all favorable.

This class of work is so dependent for speed and precision upon the weather that it is found necessary to discontinue it in the autumn when the weather gets cold and wind storms become

* Say 19 full working days: 7½ miles levelled per day gives 143 miles; 10 per cent. of this is re-levelling; the amount actually accomplished = 130 miles = 65 miles double levelling.

prevalent; the usual season for work is from sometime in April till the end of October or the early part of November.

When carrying the line of levels along the railways the elevation of the top of the rail is taken opposite each station house and at the diamond crossings of all intersecting railways; these are tabulated in the office in a separate form of record from the bench marks and are useful as giving permanent records of the work in addition to those furnished by the bench marks; they are also very useful to the companies as they furnish a means of comparing their profiles with our levels without the necessity of making any actual connections on the ground as is usually necessary in the case of bench marks.

The elevations furnished in this way are not in any degree precise, and are only calculated to the nearest tenth of a foot, but they furnish a very practical record, nevertheless, and are in demand by engineers and others.

ADJUSTMENT OF INSTRUMENTS

The collimation adjustment of the precise level is made in a manner very similar to that employed for the Dumpy level. Two solid points suitable for turning points are selected at, say, 360 feet apart and the level set up and carefully levelled at a point half way between them. The readings on the rods are made, and by subtracting them the true difference in elevation is known, regardless of whether the instrument is in adjustment or not. It is then set up with the ocular directly over one of the points on which the rod was held and the distance from the point to the centre of the aperture of the ocular is measured with a steel tape. By adding to or subtracting from this the difference of elevation of the two points, the result will be the true reading upon the rod held on the other point. Upon making this reading, should it not be within 0'·01 of the true reading, the micrometer drum is to be turned till the centre wire intersects the proper point upon the rod as indicated by the true reading, then, by turning the adjusting nut at one end of the level vial the bubble is brought again to the centre of its run and this adjustment is complete.

The line of collimation is made to revolve in a plane at right angles to the vertical axis of the instrument as follows: the bubble is brought to the centre of its run, the telescope is turned 180 degrees in azimuth, half the error — if any — is corrected by the micrometer screw and half by foot screws. For convenience the telescope may be placed so that the ocular is over one of the foot screws. The position of the zero of the micrometer drum — after this adjustment is made — should be noted and used when setting up the instrument at a station; the drum may be placed at this reading before using the foot screws for "levelling up." In this way this adjustment of the level will be kept constant.

So well do the precise levels hold their adjustments that it is not necessary to adjust them more than once in several weeks, though the adjustment is tried at intervals to see that it is all right. As the backsights and foresights are kept of equal length and no intermediate sights are ever taken, it is not a very serious matter if the level should be slightly out of adjustment in collimation. However, it is well to have it in adjustment, if only for convenience.

ADJUSTMENT OF NETS OF LEVELLING

When circuits of levelling are closed and when connecting links are run, it is obvious that new elevations will be obtained for bench marks at junction points, unless all work were performed with absolute accuracy, a condition which is, of course, never attained in practice. The question then arises "How much change will be necessitated in the published elevations of bench marks on the original lines of levelling?" I will again quote from the 1907 report of Mr. J. F. Hayford. He says:— "It is a great convenience to have fixed assigned elevations for bench marks — standard elevations so to speak — to which all other elevations in surrounding regions shall be referred, and to make no changes in these values unless necessary. Every change in the assigned elevations of the principal bench marks is liable to cause inconvenience to engineers outside the survey,

as well as to the survey, by making extensive changes necessary in computations based upon these assigned elevations. On the other hand, however desirable it may be to have fixed values for the elevations of the principal bench marks, and so to make no changes in those which have already been given to the public in print, it is not desirable to keep a value for an elevation unchanged, when later levelling gives a value differing from it greatly which is determined with a higher degree of accuracy. Therefore, it is never possible to adopt a final standard value for the elevation of any bench mark unless it is positively known that no more precise levelling connected with the net will be done, or else that, if done, it will not be utilized to improve the existing assigned elevation; for all new levelling, besides giving elevations for points not previously determined, affects, by its connections, many elevations in the net as already adjusted, the effect being necessarily greater in the vicinity of the new levelling than in regions more remote. But if all new levelling is to be utilized to the fullest extent in securing elevations of the highest degree of accuracy in every part of the net, then whenever new levelling forming links in the net is secured, the whole net must be readjusted and the old adjusted elevations must be completely superseded by the new.

"Neither of the radical plans indicated above — either to hold all old elevations without change and merely to fit new levelling to the old, or to supersede all old elevations by new ones, — seems desireable. But a conservative procedure, intermediate between the two is possible.

"If, after a complete readjustment of the level net the change in the published elevation of any junction point required by the new adjustment is very small, or in other words, elevations from the old and new adjustments agree closely, it seems best to hold the elevations already published. Especially does it seem certain that whenever the change called for by the new adjustment is much smaller than the uncertainties in the new adjusted elevations, no change should be made. So, also, when for any link in the net the new adjustment gives a difference of

elevation far within the limits of uncertainty of the new adjusted difference, it seems that the old difference of elevation should be held without change, even though a constant correction to the elevations along the line is found to be necessary."

In India, where a system of levelling has been carried on since 1858, a complete report has lately been published by the Great Triangulation Survey in which a thorough adjustment of all precise levelling up to 1909 is made, by the method of least squares; before this publication, arbitrary methods of adjustment were adopted, in most cases by giving infinite weight to the older lines and then fitting the new levelling into the old. So great discrepancies arose, however, that a complete readjustment, by a scientific method was found to be necessary. I will quote from this volume as follows:—

"It is necessary to point out that in the future we shall have to relapse again into the arbitrary methods that we are denouncing and abandoning. In this volume the circuit errors will be adjusted and the heights of all bench marks erected between 1858 and 1909 will be fixed. Any level lines subsequently observed will have to be fitted to the adjusted level net. The lines forming the level net will thus be accorded a greater weight than those observed subsequently to the reduction of the level net; from a scientific point of view this is not quite satisfactory, seeing that the future lines of levelling which should be more accurate than the old, will be subordinated. But we are in the same dilemma as our predecessors, and we cannot postpone publication of results, or wait for a finality which is unattainable. Topographers and engineers, who make use of our bench marks, only ask us to eliminate contradictions and to provide them with accordant values of height, such as they can regard as final; they deprecate frequent modifications and disturbances of values.

"This volume will, therefore, furnish values of heights sufficiently reliable to serve all purposes for, at least, half a century. In 1958 it will be open to our successors to reconsider the question and to readjust the level net of India. By that

time there should be a second level net superimposed on the first ; the second will consist of all lines observed between 1908 and 1958, and will be attached to new open coast tidal stations which have not as yet been connected with the levelling network. The second level net (1908-1958) will be a more scientific work than the present one (1858-1908). It will then be interesting to see what differences in value will occur in the heights of those bench marks that are common to both nets."

In the adjustment of this Indian level net the weights assigned to the different lines were made proportional to the reciprocals of the lengths of the lines. There were 86 lines of levels forming 29 circuits, which were tied to mean sea level at 9 points ; these 9 tidal points were given infinite weight in the adjustment, and the elevations of all the junction points in the net were computed by the method of least squares. The correct elevation of the junction points and of the terminals of lines being given, the corrections to the observed heights of intermediate bench marks on the main lines were interpolated between the terminal points. In the interpolation on any particular line the corrections were assumed to vary at a uniform rate along the line. For any branch line that terminated without a second connection with a main line or with sea level, a constant correction was applied throughout, equal to the correction applied to the height of its junction point with the main line.

The problem of making adjustments has not come up as yet with us in Canada, for, as was mentioned earlier in this paper, only two circuits of our own levelling have been closed — in Western Ontario — and they were only completed at the end of last season. It is satisfactory to note that there are no large errors of closure to be disposed of there.

MEAN SEA LEVEL

As all elevations are derived from mean sea level it is important that this should be accurately determined and that the points selected should be such that the sea level at them will not be

affected by local influences. In this connection let me quote again from the report of the Great Triangulation Survey of India : —

" The mean level of the sea is the zero or datum surface from which the elevations of the bench marks of India have been measured. In 1909 a selection had to be made of the tidal observatories, which were to form the basis of the levelling net, and which were to furnish data for the determination of mean sea level. There were three alternative courses open, namely :—

1. One reliable tidal observatory could have been chosen, and the height of the whole level net could have been based upon the mean sea level at this point ; or

2. The values of mean sea level, derived from all tidal observatories connected with the level net, could have been introduced into the levelling adjustment ; or

3. The results obtained from selected tidal observatories could be retained and those from other observatories rejected.

" The first alternative was not considered satisfactory. The mean sea level at any point may be permanently influenced by winds and currents ; and the tidal observations may be affected by instrumental errors. At no station does the annual determination of mean-sea-level reproduce the values obtained in former years. As these uncertainties exist, it seemed inadvisable to base the whole net upon the measurements at one port.

" The second alternative plan by which all tidal observations were to be included, was investigated and rejected. The levelling operations have shown that the mean-sea-level in certain confined places, such as the Gulf of Cutch and the mouth of the Hooghly, is abnormal, and permanently deformed. At these points the mean water level differs from the mean surface of the open sea by amounts greater than the probable error of levelling, and it was considered incorrect to force the levelling into accord with the tidal determinations.

" So long as the error of a determination of mean-sea-level is clearly larger than the error accumulated in the levelling, the

rejection of the tidal result may be considered advisable. But in the case of some tidal observatories the evidence is very doubtful. The selection or rejection of tidal stations then becomes a difficult question, and one that can only be settled arbitrarily. It must be remembered that the tidal stations are required to form the foundations of the levelling net, that they are expected in fact to give to the levelling in their respective localities more reliable values of height than the levelling can bring from any distant tidal observatory. It is futile then to endeavor to test their reliability by means of levelling results, which they themselves are intended to control. We must either accept the one or the other as the more correct; we cannot utilize each in turn as the test of the other.

"If the observed difference of elevation between the mean-sea-level at different ports, connected by levelling, is considerably greater than the error to which levelling is ordinarily liable, it may be assumed that the two sea levels do not belong to the same level surface. But no definite conclusions can be drawn, when the observed difference of elevation is very small; in such a case the two sea levels have not been proved to belong to one level surface. The accordance of results may be fortuitous and due to the error of the levelling having the same sign and effect as the actual difference of sea levels, or to the levelling errors having a tendency to cancel the errors of tidal measurements.

"The selection of tidal observatories on which to base the levelling net, has been, therefore, governed by general principles, and not by any observed accordance of results. It has been decided, firstly, to select open-coast stations, at which successive annual determinations of mean-sea-level have proved accordant, and secondly, to reject tidal observatories situated in channels, gulfs, creeks or rivers, and those at which annual determinations of mean-sea-level appeared discordant.

"The variations of mean-sea-level.— When we refer to variations of mean-sea-level we mean always variations relative to the level of the land surface. The movements of the earth's

crust are of two descriptions — the gradual and the sudden; there are, firstly, the slow imperceptible elevations and subsidences of possible immense areas, and, secondly, the sudden changes caused by earthquakes.

"The branch line of levels from Saharanpur to Mussooree is the only line in India that has, so far as we know, been disturbed by an earthquake. We have, moreover, no evidence that any of our bench marks have been disturbed by slow gradual movements of the earth's crust; . . . . . we have the annual determination of mean-sea-level made at nine different tidal observatories, and we have been unable to detect in them any tendency to constant change in one direction. The mean-sea-level has been shown, it is true, to vary annually, but it seems to oscillate from year to year about one mean position."

These conclusions will have to be taken into consideration when determining upon a mean-sea-level datum for the Geodetic Survey of Canada, if it is decided to abandon that of New York, which we take up at Rouse Point.

PROGRESS AND PUBLICATION OF RESULTS

Levelling operations are at present being carried on vigorously by this Department; during the last two seasons three completely equipped parties have been in the field, in 1910, 812 miles of completed levelling was accomplished and during 1911, 893 miles. The total amount to date is 2627 miles, that is to say, this distance has been run forward and the same distance backward, no account being taken of the additional re-levelling done.

Seven hundred and forty-eight bench marks (all of the copper bolt variety described above) have been established since the beginning of the work, this number does not include any that are known to have been since destroyed, but only those actually in existence and connected to the lines of levels.

The question of publishing the results of the work for the benefit of the public was not taken up till about the beginning of

last year, as it was desired to have the work on a sound basis and to have some connection with other datums before doing so. The Chief Astronomer's Report for 1910, now in course of preparation, contains the complete descriptions and elevations of bench marks and rail levels at stations for some 840 miles in Ontario, Quebec and New Brunswick, and the 1911 Report will probably contain additional results to the amount of 850 miles or thereabouts.

DOMINION OBSERVATORY,
OTTAWA, CANADA.
February 23, 1912.

A LONG-PERIOD SPECTROSCOPIC BINARY

By W. E. Harper

THE second magnitude star γ Geminorum ($6^h\ 31^m{\cdot}9$, $\delta = +16^\circ\ 29'$) has been under observation here since the autumn of 1906. Its radial velocity had previously been investigated by Campbell, Frost and Slipher in the years from 1899 to 1905 and it was also one of the stars which Vogel used at Potsdam when the photographic plate was first applied to work of this nature in 1888. When we consider that the two plates secured by Vogel which are used in this paper were made at the very beginning of radial velocity work the residuals of 1·5 km. for each are very small. Although a few more measures were made at Potsdam they are not used, for the reason that only the H_γ line on each was measured, and consequently the same reliance could not be placed upon them as on plates where many lines were measured.

Of the four Lick observations two were made in 1899, one in 1904 and one in 1905. The 1904 plate showed variability in velocity and the star was announced as a spectroscopic binary in the *Astrophysical Journal* for March, 1905. The Yerkes Observatory made three plates in 1901 which showed no variation in velocity and one in 1904 which did. The Lowell Observatory have a plate in each of 1902 and 1903 and four in 1905. As the 1905 plates were all made within a month and are only approximate results, they can not be considered as better than two definite measures. For some reason the 1902 plate does not agree with our curve there being a residual of 9 km. in a well defined part of the curve, while the 1903 plate has a residual of 3 or 4 km., but in a part of the curve which is not so well defined and which will require more observations to fill up the gap. As none of the other plates used gave residuals greater than 2 km. these

two plates were excluded from the final determination of the orbit. Just at this point it may be stated that Slipher, using the data just outlined, which is given in the table of "Early Measures," discussed the star's variable velocity in *Astrophysical Journal*, Vol. XXII., page 84, and suggested for it a period of three and one-half years. The observational data was, however, entirely too meagre, I think, to bear out any suggested period. The period herein determined, approximately six years, is no multiple of that suggested by Slipher and the writer feels that though the number of observations is greatly increased they are yet too few to make a rigid determination of the elements. Those given here suit the observations remarkably well however.

Twenty plates were made here with the Universal three-prism spectrograph from December, 1906, to April, 1907. These were measured and reduced by the writer, using the long interpolation method of Hartmann. As twenty or more star lines on each were measured, a considerable amount of labor was thus expended on them. This work availed little so far as the star itself was concerned, but, possibly, helped to show that some instrumental errors had not yet been overcome and a new spectrograph was accordingly designed for radial velocity work alone. The plates with the Universal instrument have, therefore, not been used in this discussion.

The new three-prism spectrograph, IIIL, was ready in May, 1907, and spectrograms of the star were again made. During the season of 1910 the spectrograph was changed quite frequently, as a short form of camera was being experimented on, and no plates with the long focus camera were made. There were made, however, two with camera designated III S and one with camera designated III R, but as the dispersion of these was only about one half as great as the III L, they could not be considered by any means as reliable as the other, and hence they have not been used. It is unfortunate that a continued series of plates with III L were not made that season as they would fall around the maximum of the curve and round out an otherwise incomplete set. The plates then that are used in this discussion were all

made with spectrograph III L, whose linear dispersion at H_γ is 10·1 tenth-metres per millimetre. The measures of these are given in the table. Quite a number of these results are the means of two measures. Nearly all the plates were measured by the writer, but independent measures were made on several by other observers, Messrs. Westland, Cannon and Parker, and there was good agreement in the results obtained. The phases are reckoned from the corrected value of periastron passage, Julian Day 2,410,101·6, using the period 2175 days.

EARLY MEASURES

Observatory	Date	Julian Date	Phase	Velocity	Wt. Assigned	Residual
Potsdam	1888, Dec. 14	2,410,986·5	896·4	− 18·1	½	+ 0.5
Potsdam	1889, Jan. 6	1,009·5		14·2	½	
Lick	1899, Sept. 21	4,919·9	468·3	15·4	1	− 1·0
Lick	Oct. 24	4,952·9	501·3	15·1	1	− 0·4
Yerkes	1901, Nov. 15	5,704·8	1253·2	15·4	1	+ 0·3
Yerkes	Nov. 20	5,709·8	1258·2	14·9	1	+ 0·8
Yerkes	Nov. 27	5,716·8	1265·2	16·4	1	− 0·7
Lick	1904, Jan. 27	6,507·8	2056·2	4·7	1	+ 0·1
Yerkes	Dec. 6	6,821·8	195·2	8·7	1	+ 0·2
Lick	1905, Feb. 13	6,890·7	264·1	10·4	1	+ 0·2
Lowell	1905, Mar. 10	6,915·7	294·1	11·	½	− 0·2
Lowell	Mar. 20	6,925·7		12·	½	
Lowell	Apr. 6	6,942·6	319·5	11·	½	+ 0·4
Lowell	Apr. 13	2,416,949·6		11·8	½	

OTTAWA MEASURES OF γ GEMINORUM

Plate	Date		Julian Date	Phase	Velocity	No. of Lines	Wt.	Residual
1099	1907,	Oct. 8	2,417,857·9	1231·3	− 15·9	13	1	0·0
1255	1908,	Jan. 22	7,963·5	1336·9	14·7	10	1	+ 0·5
1293		Jan. 27	7,968·8	1342·2	15·5	17	1	− 0·3
1305		Jan. 29	7,970·8	1344·2	13·8	16	1	+ 1·3
1330		Feb. 17	7,989·8	1363·2	16·9	17	1	− 1·8
1307		Feb. 28	8,000·7	1374·1	14·4	15	1	+ 0·5
1453		Apr. 3	8,035·7	1409·1	15·5	15	1	− 0·8
1872		Sept. 7	8,192·9	1566·3	12·6	10	1	+ 0·5
2074		Dec. 23	8,299·7	1673·1	10·4	14	1	+ 1·2
2208	1909,	Jan. 30	8,337·7	1711·1	12·9	16	1	− 1·8
2281		Feb. 17	8,355 7	1729.1	11·9	14	1	− 1·1
2287		Feb. 20	8,358·7	1732·1	9·9	11	1	+ 0·8
2395		Mar. 20	8,386·7	1760·1	9·5	15	1	+ 0·7
3071	1911,	Jan. 28	9,065·8	264·2	11·4	13	1	− 0·8
4734		Dec. 19	9,390·9	589·3	15·2	13	1	+ 0·3
4830	1912,	Feb. 8	2,419,441·8	640·2	− 16·3	15	1	− 0·4

The spectrum is of the Sirian type, having many fine metallic lines of iron and titanium as well as the hydrogen series. The following table contains the lines most frequently measured.

LINES IN γ GEMINORUM

Element	Wave-Length	Element	Wave-Length
Fe	4584·018	Ti	4468·663
Ti	4572·156	Ti	4443·970
Ti	4563·939	Fe	4404·927
Cr	4558·827	Ti-V-Fr	4395·286
Fe Cr	4556·202	Cr-Mg.	4352·000
Fe-Ti	4549·765	H_γ	4340·634
Ti	4534·139	Fe	4325·939
Fe-Ti	4522·855	Fe	4308·081
Ti	4515·508	Ti	4300·211
Ti	4508·455	Fe	4294·290
Ti	4501·448	Fe	4233·328
Mg.	4481·400		

It has been the writer's custom for some time past to obtain wave-lengths for each star by itself, making the sum of the velocity residuals equal to zero. In the case of this star a summary of the residuals given by each line from the velocity

accepted for the plate shows that some slight changes might be made in the wave-lengths and better agreement secured among the lines themselves. The revised velocities would not be materially different, as the differences in the long run would tend to balance one another, and the procedure has not been carried out. A sample of the residuals is given in the accompanying table for the nine lines most frequently used, the order indicating the frequency of measurement.

RESIDUALS FROM LINES

Line	Average Numerical Residual	Average Algebraic Residual	Line	Average Numerical Residual	Average Algebraic Residual
4549	2·3	+ 0·8	4522	2·7	+ 1·4
4481	1·9	− 1·4	4501	2·2	− 1·6
4534	5·1	− 1·7	4395	5·0	+ 3·7
4352	2·9	+ 0·8	4508	2·6	− 2·0
4308	2·5	+ 1·2			

A plot of our own observations seemed to indicate a period of about six years. The early observations were now brought forward using periods of 2270, 2200 and 2160 days. The latter seemed to suit the reliable observations, best and it was accordingly used. Graphical values for the elements were obtained in the usual way.

Preliminary Elements

P = 2160 days
e = ·35
ω = 0°
K = 6·5 km.
γ = − 12·27 km.
T = J. D. 2,410,036·0

Although, as previously stated, there was a gap in the curve requiring further observations to fill up, yet it seemed desirable to make a least squares solution of all the dependable measures to date. For purposes of grouping, the very early observations at Potsdam were weighted one-half as were also the Lowell approximate measuress, while all others including our own were each

weighted unity. In the Table of Normal Places groups 1–9 inclusive represent our own observations, groups 10–16 those of other observatories.

TABLE OF NORMAL PLACES

	Mean Phase Preliminary	Mean Vel.	Wt.	O-C Preliminary	Mean Phase Corrected	O-C Corrected
1	1394·7	− 15·30	2	+ ·43	1284·1	+ ·24
2	1453·8	14·65	2	+ ·74	1343·2	+ ·50
3	1479·2	15·65	2	− ·44	1368·6	− ·68
4	1598·3	14·05	2	+ ·07	1487·7	− ·12
5	1802·7	11·65	2	− ·52	1692·1	− ·31
6	1841·2	10·90	2	− ·58	1730·6	− ·19
7	1870·7	9·50	1	+ ·15	1760·1	+ ·71
8	389·8	11·40	1	+ ·35	264·2	− ·70
9	740·3	15·75	2	− ·15	614·8	− ·04
10	962·0	16·10	1	+ ·29	896·4	+ ·55
11	580·4	15·25	2	− ·88	484·8	− ·75
12	1354·5	15·57	3	+ ·36	1258·9	+ ·12
13	2151·8	4·70	1	− 1·19	2056·2	+ ·11
14	340·2	9·55	2	+ 1·24	229·6	+ ·21
15	404·7	11·50	1	+ ·52	294·1	− ·21
16	430·1	− 11·40	1	+ 1·04	319·5	+ ·44

Observation equations using the differential form of Lehmann-Filhés were built up and transformed into normals from which the following corrections were obtained.

$$\delta\gamma = - \cdot 01 \text{ km.}$$
$$\delta K = - \cdot 38 \text{ km.}$$
$$\delta e = - \cdot 052$$
$$\delta \omega = + 16^\circ \cdot 31$$
$$\delta P = + 15 \cdot 0 \text{ days}$$
$$\delta T = + 65 \cdot 6 \text{ days.}$$

Using the corrected value of the period, 2175 days, the observations were again grouped as in column 6 of the table, and residuals obtained which were in general smaller than the previous ones. The value for Σpvv for the preliminary elements was 11·1 and for the corrected elements 4·7. Using all the measures the probable error of a plate obtained from the last two columns of the measures is ± 0·55 km. per sec. This is extremely small for a star of this type when we consider that

the plates were secured by five different equipments, and one cannot but feel that the good agreement is somewhat of a chance result. This is all the more likely when we note the probable errors of the determined quantities which appear with the corrected values of the elements. Some of them are of considerable magnitude, and it will be necessary to obtain more measures after a few years to fill up the gap at the maximum of the curve. The elements as corrected, with probable errors, are as follows:

Corrected Elements

$P = 2175 \pm 22{\cdot}85$ days
$e = {\cdot}298 \pm {\cdot}026$
$\omega = 16°{\cdot}31 \pm 6°{\cdot}16$
$K = 6{\cdot}12$ km. $\pm {\cdot}28$ km.
$\gamma = 12{\cdot}28$ km. $\pm {\cdot}13$ km.
$A = 7{\cdot}87$ km.
$B = 4{\cdot}37$ km.
$T =$ J. D. $2{,}410{,}101{\cdot}6 \pm 96{\cdot}81$ km.
$a \sin i = 174{,}720{,}000$ km.

This star is unique in being one of the longest period binaries known. With the exception of α Orionis, a late solar type star, which has recently been shown* to have a period approximately the same, but whose orbital elements have not been definitely determined, no other spectroscopic binary has nearly such a long period. The other binaries of this type have periods ranging from a fraction of a day up to one hundred days. In the case of Sirius the period is 49·3 years, but it was not from spectroscopic but from visual observations that this was determined.

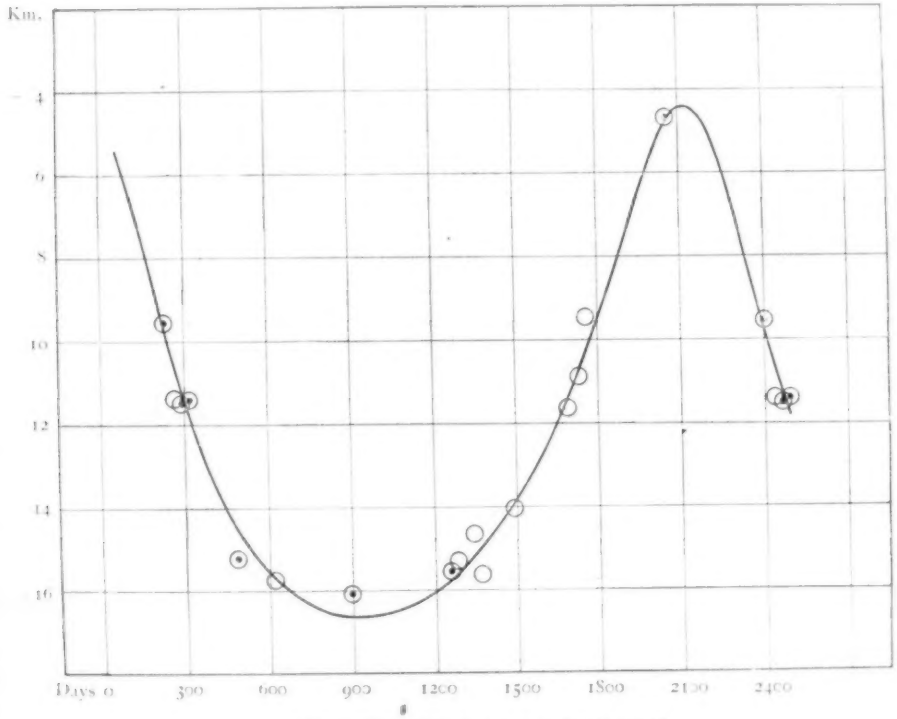
The periods of visual binaries in general are very large when compared with those of spectroscopic binaries but there are some with relatively short periods. Thus we have

κ Pegasi	11·37 years,
13 Ceti	7·42 years,
δ Equulei	5·70 years,

* *A. N.* 4467.

the last one of these has a shorter period than the star under consideration. So that we may say of γ Geminorum that it bridges over the gap between the periods of the longest spectroscopic and the shortest visual binary.

The plates were all of Seed 27 emulsion. One fine grained plate has since been made, but on none does a second spectrum show. The companion star would, of course, need to be of small mass relatively to the principal star in order that there might be sufficient separation of the lines to be resolved on our plates. Possibly near the time of next periastron passage, which occurs



VELOCITY CURVE OF γ GEMINORUM

at the beginning of 1916, some high dispersion equipment may record the fainter component spectrum. If the star should prove to be a visual binary, and we combined the spectrographic measures of the relative velocity of the two components in the line of sight with the orbit data from micrometric measures, we would have an indirect means of determining the parallax of the star. So far as is known to the writer no values of the parallax of this star by any method have been published.

The curve shown represents the elements as corrected. The plain circles represent our own observations grouped, while the circles with dark centres the grouped measures of other observatories.

It is with some hesitation that the foregoing elements are submitted. Owing to the paucity of observations around the peak of the curve we cannot regard these elements as definite, but they can be regarded, I think, as fairly approximate. It is just possible that this discussion may result in some unpublished measures of this star's radial velocity being brought to light.

A good share of the credit for this determination of the orbital elements should be given to those observatories who made the early observations, without which our own measures would be inadequate.

DOMINION OBSERVATORY,
OTTAWA, CANADA,
April, 1912.

ORBIT OF ξ PERSEI FROM THE H AND K LINES

By J. B. Cannon

ξ PERSEI is one of those stars in which the velocities given by the H and K lines of calcium differ greatly from those from the broad lines of hydrogen and helium. The spectrum is placed by Miss Cannon in the Oe 5 B class. The lines showing are those of hydrogen, helium and calcium. A few iron lines appear, but not with sufficient frequency to make them useful for measurement. The hydrogen and helium lines are very broad and ill-defined, the latter lines especially being very poor. The calcium lines are fairly good, sometimes both being easily measurable, sometimes only one and in some cases neither appears sufficiently defined to make measurement possible.

The first published measures of this star appeared in *Astrophysical Journal*, Vol. XVIII., p. 383, 1903, five measures being given of the broad lines in an article by Professor Frost under the heading — "An Orion Star of Great Radial Velocity." The range — 9 kilometres — was not considered sufficient ground to pronounce it a binary. Later in *Astrophysical Journal*, Vol. XXIX., p. 236, 1909, Professor Frost announced another measure of this star giving a range of 30 kilometres. In that note he remarked that the H and K lines have a moderate positive velocity with a range of about 25 kilometres, these lines differing greatly in the velocities shown from the values derived from the broad lines.

Observations on the star were first made here in 1908, a few plates being taken. It was then dropped from the observing list until 1910, and plates were taken in the seasons of 1910-11 and 1911-12. Although the broad lines were measured at first, — where measurement was possible, — as well as H and K, it was not felt that these diffuse lines would be of any aid in ascer-

taining anything in regard to the orbit of the star, and attention was given almost exclusively to the H and K lines of calcium. These lines were not always found on the plates, but generally one or other of them was well enough defined to be measured. Of the 1908 plates only two gave measures of K which were considered reliable. Of the later plates — 1910-11-12, 41 plates were good enough to be useful in the determination of the orbit. The later plates were all Seed 23 and were much better than the earlier ones of Seed 27, although the fine-grained plate did not serve to make the broad lines measurable. As stated above, these broad lines were measured at first. An attempt was also made to get measures on the members of the second series of hydrogen with a view to determining the wave-lengths of these lines in this star, but the utter impossibility of anything definite in this regard led to the abandonment of the attempt.

The wave-lengths used for H and K were 3968·625 and 3933·825 respectively. K was, with very few exceptions, stronger than H. Some plates were found in which H and K gave widely different results. In such a case, if the lines were equally good, the plate was left out of consideration : if one was much better than the other that line was used.

Great aid was given in the work by the use of Yerkes measures of ten plates kindly sent me by Professor Frost, and of nine more plates loaned by Professor Frost and measured by me. As a check on the measures of a plate — here and at Yerkes,— two plates — I B 141 and I B 402,— were measured at both places. On one of these, I B 402, the measures were practically the same, but on the other — not too well-defined — a difference of ten kilometres was found. Of the nine plates taken at Yerkes and measured here, unfortunately four of them gave H and K differing considerably, while one of them gave only H measurable. Otherwise the Yerkes plates fit the accepted curve as well as can be expected from a spectrum which gives only one and at most two lines on which to base results.

Table I. gives Ottawa Observations ; Table II. Yerkes Observations.

TABLE I.—OTTAWA OBSERVATIONS

Plate	Julian Day	Phase	Vel.	Wt.	Lines	Residual	Remarks
1974	2,418,266·83	4·620	+18·0	½	K	- 4·7	
1999	280·72	4·613	+26·0	¼	K	+ 3·4	
3740	957·83	0·522	+10·3	1½	H & K	- 0·3	
3765	964·81	0·552	+ 4·9	½	K	- 5·4	
3777	970·91	6·653	+16·0	1½	H & K	- 0·3	
3817	9,011·61	5 653	+36·0	⅞	H & K	+13·8	
3861	018·68	5·763	+22·0	1½	H & K	+ 0·2	
3881	022·79	2·922	+14·2	½	K	+ 1·0	
3915	042·54	1·822	+ 7·5	1½	H & K	- 0·4	
3921	046·54	5·823	+36·0	1	K	+14·4	
3929	049·55	1·882	+ 2·7	½	K	- 5·5	
3936	053·58	5·913	+24·7	⅞	K	+ 3·6	
3957	055·57	0·952	+ 6·3	½	K	- 2·2	
3962	056·58	1·962	+ 3·6	1½	H & K	- 4·9	
3974	067·66	6 083	+16·2	½	H & K	- 4·1	
3991	079·56	4·083	+13·3	1	K	- 7·0	
4020	091·58	2·202	+15·0	1	K	+ 5·8	
4056	102·50	6·173	+16·5	¼	K	- 3·2	
4067	103·52	0·242	+ 5·4	½	K	- 6·9	
4552	293·89	2·932	+ 4·3	¼	K	- 8·9	
4634	322·77	4·113	+17·4	1	K	- 3·3	
4645	323·81	5 053	+30·5	½	H & K	+ 7·2	
4676	343·66	4·053	+25·1	1	H & K	+ 4·8	
4685	344·74	5·133	+15·8	½	K	- 7·4	
4690	351·71	5·143	+16·8	1	K	- 6·4	
4715	377·59	4·303	+30·8	¼	K	+ 9·3	
4729	390·60	2·332	+ 5·4	⅞	K	- 4·4	
4738	396·70	1·482	+15·5	1	H & K	+ 7·9	
4745	403·58	1·402	+11·0	¼	K	+ 3·3	
4758?)	412·50	3·372	+16·8	⅜	H & K	+ 0·8	
4759)					K		
4779	414·60	5·473	+18·5	1	K	- 3·7	
4801	421 62	5·543	+21 0	1½	K	- 1·6	
4819	428·56	5·533	+15·0	1	K	- 7·6	
4828	434·51	4·533	+21·8	1½	H & K	- 0·5	
4831	443·52	6·593	+21·2	¼	K	+ 4·4	
4833	445·55	1·672	+11·9	⅞	H & K	+ 4·2	
4839	446·53	2·652	+ 7·3	1	H & K	- 4·2	
4843	447·53	3·653	+21·6	1½	H & K	+ 3·6	
4849	453·56	2·732	+14·0	1½	H & K	+ 2·0	
4853	456·58	5·753	+17·8	1	K	- 4·0	
4858	461·54	3·763	+21·6	⅞	H & K	+ 2·9	
4869	467·55	2·822	+14·2	¼	K	+ 1·7	
4874	468·55	3·813	+15·6	½	K	- 3·2	

TABLE II.—ξ PERSEI, YERKES PLATES

MEASURED AT YERKES

Plate	Julian Day	Phase	Vel.	Wt.	Lines	Residual	Remarks
I B							
101	2,416,384·86	6·371	+ 23			+ 4·5	
119	404·81	5·468	+ 29			+ 6·2	
141	411·78	5·487	+ 6			- 16·6	Cannon's measure + 116·0 Residual - 6·6.
179	426·79	6·595	+ 10			- 6·7	
203	450·66	2·661	+ 23			+ 11·4	
232	476·50	0·697	+ 10			+ 0·5	
304	586·60	6·532	+ 24			+ 6·7	
402	754·93	1·087	+ 2			- 6·1	
465	845·56	1·354	+ 12			+ 4·3	
821	7,433·89	5·800	+ 23			+ 1·5	

MEASURED BY CANNON

Plate	Julian Day	Phase	Vel.	Wt.	Lines	Residual	Remarks
I B							
850	2,417,468·90	6·055	+ 14·5	¼	K	- 6·0	
879	496·84	6·201	+ 4·5	¼	K	- 15·0	
935	580·56	6·499	+ 19·3	¾	H & K	+ 1·8	
1199	860·81	1·758	- 0·5	½	K	- 8·3	H & K differ
1208	867·75	1·747	- 5·9	½	K	- 13·7	H & K differ
1216	869·76	3·757	+ 13·7	1½	H & K	- 4·8	
1260	910·68	2·971	+ 3·4	½	H	- 9·9	H only
1289	926·58	4·969	+ 7·9	1	K	- 15·3	H is highly + ve
1350	961·51	5·144	+ 18·6	1	K	- 4·0	H is much more + ve

The period finally decided on after a great many trials was 6·951 days. There are some fairly large residuals but the probable error of an average plate is ± 3·6, and that is very satisfactory when one considers that many values are dependent on one line which is not always very well defined.

The observations were grouped into eleven normals which appear in Table III. (The phases are from the final T).

TABLE III.

No.	Julian Day	Phase	Vel.	Wt.	Residual
1	2,419,342·88	3·893	+ 19·42	3	+ 0·19
2	2,419,040·51	4·550	+ 22·42	1	+ 0·19
3	347·99	5·123	+ 19·98	1	− 3·22
4	349·25	5·543	+ 21·65	2	− 0·98
5	141·60	5·803	+ 24·96	2	+ 3·26
6	082·24	6·433	+ 17·36	1·5	− 0·62
7	8,988·36	0·472	+ 8·24	1	− 2·57
8	9,300·21	1·322	+ 12·23	1	+ 4·65
9	128·76	1·852	+ 6·44	2	− 1·48
10	302·20	2·412	+ 9·56	1·5	− 0·44
11	367·68	2·942	+ 13·95	1·5	+ 0·85

Preliminary elements for the orbit follow :—

$$\text{Period} = 6{\cdot}951 \text{ days}$$
$$e = {\cdot}1$$
$$\omega = 150°$$
$$K = 7{\cdot}75 \text{ km.}$$
$$T = 2{,}418{,}249{\cdot}349 \text{ J. D.}$$
$$\gamma = + 15{\cdot}92 \text{ km.}$$

Observation equations were formed and normal equations from them, and a solution put through with the object of getting a closer approximation to the true orbit. This resulted in corrections to the elements as follows :—

$$\delta\gamma = - {\cdot}52$$
$$\delta K = \pm {\cdot}00$$
$$\delta e = - {\cdot}11$$
$$\delta\omega = -22°{\cdot}47$$
$$\delta T = - {\cdot}496 \text{ days.}$$

There is one peculiarity about these corrections, δe has the value − ·11 whereas the preliminary value is only ·1. This would seem to indicate that the orbit is circular and ω indeterminate. This will be further seen from the oscillations in the value of ω in the following operations. New preliminary values were taken in which

$e = \cdot 05$
$\omega = 60°$
$K' = 7 \cdot 75$ km.
$T = 2{,}418{,}247 \cdot 607$ J. D.
$\gamma = 15 \cdot 06$ km.

It might be stated here that the value of Σpvv was reduced by the solution, the corrected e being taken as zero, from 74·7 to 73·2. With the new preliminaries the value was 72·5. It was apparent that any solution would fail to make much reduction in the value of Σpvv the signs being well distributed in the residuals. However a least-squares solution was made with the new preliminary values. The resulting corrections were as follows :—

$\delta \gamma = + \cdot 34$ km.
$\delta K' = + \cdot 12$ km.
$\delta e = + \cdot 022$.
$\delta \omega = + 81° \cdot 80$
$\delta T = + 1 \cdot 511$ days,

whence we obtain the new values —

$\gamma = 15 \cdot 40$ km.
$K' = 7 \cdot 87$ km.
$e = \cdot 072$
$\omega = 141° \cdot 80$
$T = 2{,}418{,}249 \cdot 118$ J. D.

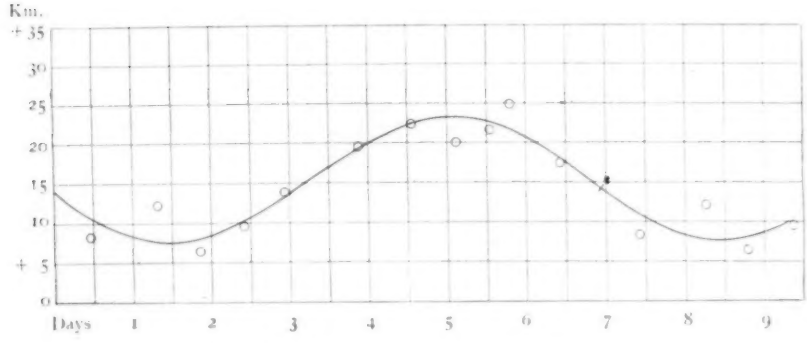
It is rather strange that e and ω should have come back to so nearly the original value. Σpvv was reduced from 72·5 to 69·5. The agreement between computed and observation equation residuals was bad and a third solution was made for the sake of completion. The corrections found were :

$\delta \gamma = \pm \cdot 00$ km.
$\delta K' = \pm \cdot 00$ km.
$\delta e = - \cdot 038$
$\delta \omega = - 42° \cdot 62$
$\delta T = - \cdot 810$ days,

and hence the final elements —

$$P = 6{\cdot}951 \text{ days.}$$
$$K' = 7{\cdot}87 \text{ km.}$$
$$\gamma = 15{\cdot}40 \text{ km.}$$
$$e = {\cdot}034$$
$$\omega = 99°{\cdot}18$$
$$T = 2{,}418{,}248{\cdot}308$$

A summary follows showing results of the various solutions made in the determination. The probable errors of the elements are added in the last column.



VELOCITY CURVE OF ξ PERSEI

Summary

	Element	Preliminary	After 1st Solution	New Preliminary	After 2nd Solution	After 3rd Solution
P	Period	6·951 days	6·951 days	6·951 days	6·951 days	6·951 days
K	Half-Amplitude	7·75 km.	7·75 km.	7·75 km.	7·87 km.	7·87 km. ± 0·80
γ	Vel. of system	15·92 km.	15·40 km.	15·06 km.	15·40 km.	15·40 km. ± 0·60
e	Eccentricity	·1	− ·01	·05	·072	·034 ± ·114
ω	Angular distance of Periastron from ascending node	150°	127°·53	60°	141°·80	99°·18 ± 15°·49
T	Time of Periastron passage	2,418,249·349 J. D.	.... 248·853	.... 247·607	.... 249·118	.... 249·308 ± 1·575
$a \sin i$	½ Major axis × sine of inclin.					751,800 km.
	Prob. Error of Nor. Place, Wt. Unity					± 2·3 km.
	Σpvv	74·7	73·2	72·2	69·5	68·2

After the completion of the orbit-determination from the calcium lines, the results from the broad lines were reviewed. The diffuseness of the lines, however, and consequent uncertainty of the measures from them made it quite impossible to secure any reliable information from them. Some information in regard to these lines would have been very interesting, but it seems that so far we must be content with the one fact which seems assured — the broad lines show a much higher positive velocity than the H and K lines.

In conclusion I wish to thank Dr. King for the interest he has shown during the progress of this work.

DOMINION OBSERVATORY,
OTTAWA, CANADA
June, 1912

MEETINGS OF THE SOCIETY

At Toronto.

May 14.—The meeting was held in the Society's Rooms, 198 College Street, at 8 p.m.

Professor G. R. Anderson gave the lecture of the evening on "The Scientific Application of Photography."

The lecturer first gave a sketch of the early history of photography. Then he gave an instance of optical illusion (Zöllner lines) showing the advantage of photography over direct observation in astronomy. Other advantages were enumerated. Several astronomical photographs were shown to exhibit the advantages secured by long exposure in the revelation of faint detail. Then followed the application of photography to physical processes, *e. g.*, photography of a moving bullet, and the analysis of sound waves. Next the question of spectrum photography was discussed, pictures of spectra being shown; and the production of spectra, continuous, and discontinuous, was explained, mention being made of the significance of absorption lines in the spectrum of sunlight. Illustrations were also given of X-ray photographs, of lightning flashes, and of microphotographs. Many other interesting applications were given, all being illustrated by admirable lantern slides.

May 28.—The meeting was held in the Society's Rooms at 198 College Street, at 8 p.m.

Mr. E. Willems, 3 Moss Park, Toronto, and Mr. F. Hooker, 32 Sinclair St., Toronto, were elected members of the Society.

Mr. Mason and Mr. Barker suggested that the Society communicate with the Young Peoples Societies of the City with the object of having them take an interest in Astronomy. This matter will be taken up in the autumn.

Moved by Mr. Collins, seconded by Dr. Wunder that the next meeting be an open-air meeting to be held on Tuesday, June 4th.

Mr. J. R. Collins gave a paper on "Summer Constellations." He first explained the method of determining the position of a star, and the meaning of right ascension, and declination. In getting the general position of constellations, Ursa Major, Ursa Minor and Cassiopeia were used as reference positions. Several of the constellations were described, and with the aid of diagrams and slides, the motions of the planets, and the positions of the constellations at different seasons were made clear.

L. G.

At Ottawa

May 9, at the Dominion Observatory, at 3 p.m.—Dr. R. E. DeLury gave a paper on "The Solar Rotation." This paper was closely connected with a paper on the same subject by Mr. J. S. Plaskett, given December 7, 1911. As Mr. Plaskett's paper had explained fully the methods of observation followed and described, the instrumental equipment employed and the precautions necessary to obtain accurate values, Dr. DeLury only outlined briefly these particulars and then devoted his time to the discussion of results.

Sixteen plates, having the rotation effects from seven different latitudes of the sun on each, had been measured by Dr. DeLury with a view to throwing light on the following questions:

1. What is the law of variation of rotation with changing latitude?

2. Is there any periodical variation in the solar rotation?

3. Do different elements rotate at different rates?

Before accurate answers can be given to these questions all systematic errors must be eliminated. So far as known, the

instrumental errors were eliminated, but there remained the systematic personal errors of measurement which he showed to be present in a previous paper in which the measurements of imitation rotation displacements were considered. To eliminate these errors he devised a mask which could be readily moved from one strip of spectrum to another, thus showing the same configuration of the lines in the measurement of any line in each of the three strips of spectrum, and further keeping all knowledge of the magnitude of the displacement from the observer. Measurements of sixteen equatorial displacements made with this device were found to be systematically greater than those made previously without it. The mask saved the eye from strain and made it possible to measure all day.

Comparisons were made of measurements by Plaskett and DeLury showing serious systematic differences as follows :— For the equatorial velocity from 35 plates at λ 5600, Plaskett's value was 2·008 m. per sec., DeLury's value, 1·959 m. per sec., while for 7 plates at λ 4250, Plaskett's value was 2·006 m. per sec., and DeDury's value 1·996 m. per sec., showing that the character of the spectrum plays some part in the error. A similar tendency was found previously in the measurements of the arbitrary displacements. The values obtained by Duner, Halm and Adams were found to differ in a similar manner and undoubtedly systematic errors of measurement at least partially accounted for these differences.

Such grave systematic errors being present, Dr. DeLury thought it unwise to attempt to give definite answers to questions (1) and (2) and considered it advisable that observers of the solar rotation should take every precaution to eliminate these errors and find out their nature before doing so. With regard to question (3), both his measurements and Mr. Plaskett's indicated that no definite difference in rotation could be assigned to the different elements. Any systematic tendencies observed were of the nature of those found in the measurements of the imitation rotation plates made by means of the double-slit and on which, therefore, the displacements should be the same, and

in some cases the systematic tendencies were found to be the reverse of those found by Adams.

In the discussion which followed Dr. King and Mr. J. S. Plaskett took part.

C. E.

At Hamilton

May 10.— Mr. Samuel Beatty, M.A., Lecturer on Mathematics in the University of Toronto, lectured this evening on the subject "Astronomical Weights and Measures."

By the aid of lantern slides and blackboard diagrams the lecturer made plain the methods by which the various determinations are arrived at.

First was described the "celestial sphere" and how each day the place of the sun might be plotted upon it which would give the apparent motion of the sun about the earth.

Then from noticing the nodes the length of the year could be arrived at.

The properties of the ellipse were discussed and the three Laws of Kepler were explained.

The various methods of arriving at the solar distance were described, also the ways in which the size of the earth is arrived at, commencing with the method of Eratosthenes which, while perfectly correct in theory, is difficult to use successfully in practice.

At the close a hearty vote of thanks was tendered the lecturer for his interesting and instructive address.

T. H. W.

At Peterborough

May 6.— In the Physical Laboratory of the Collegiate Institute, Rev. Dr. Marsh gave an interesting address on "The Latest Researches on the Planets, Especially Saturn." The lecture was well illustrated with lantern slides.

The speaker first described the planet Mercury. He said it took 88 days to pass around the sun. It has an eccentric orbit and is 28,000,000 miles from the sun when nearest to it, and

was 43,000,000 miles from the sun when farthest away. It is three times larger than the moon. It has mountainous markings but no atmosphere. Its albedo, or capacity to reflect what light it receives, is 17 per cent., or the same as that of the moon. It turns on its axis in 88 days.

Venus had first been called Lucifer, because it resembled a torch ; later Hesperus, when seen in the morning ; then Vesper, when seen at night, thus originating the vesper service, and finally Venus, the goddess of love. Its diameter is 200 miles less than that of the earth. Its orbit more circular than that of Mercury and travelling around the sun in 225 days, revolving on its axis in the same time. There is a difference of opinion about the time for its rotation. It has an atmosphere like that of the earth and its albedo is 60 to 70 per cent. It is 66,000,000 miles from the sun.

Mars, he said, is a little smaller than the earth. It is 139,000,000 miles from the sun and completes its orbit in about two years. It rotates on its axis in 24 hours and 37 minutes. It has markings of snow at the north and south poles that melts in the Martian summer and increases in the Martian fall. It has other markings that some of the astronomers sometimes, but unfortunately, called artificial waterways. The atmosphere is very light and it is too cold for people from the earth to live there. Its albedo is 27 per cent.

The planet Jupiter is in the same condition as the world was, in all probability, before the water was brought together in one place. It is moist and its albedo is 65 to 70 per cent. It is 476,000,000 miles from the sun. It has a diameter of 85,000 miles. A day on Jupiter is about ten hours long. It has many moons and the velocity of light was calculated from one of them. It is eclipsed regularly but the eclipse is not seen from the earth until 16 minutes and 24 seconds later. This time is taken in the transit of the light and showed that light must travel at the rate of 186,000 miles per second.

Saturn is a planet 700 times as large as this earth. It is practically the same on the surface as Jupiter, only not quite

as old. It is what might be called a planet in the making. There are rings about it that are meteoric. The speaker believed these would eventually collapse and either become part of the planet or else turn into satellites. The atmosphere is very heavy and the albedo is the same as that of Jupiter. It has moons of different sizes.

Uranus and Neptune are very distant planets. They are so far away that to look through a five-inch telescope they appear to be about the size of a green pea. So far are they away that very little definite information has thus far been gained from them.

D. B. M.

At Guelph

March 14.—Mr. G. Parry Jenkins's lecture before the Guelph Centre of the Royal Astronomical Society on "The Orbs of Heaven," drew a large audience to the Carnegie Hall, and proved to be one of the most interesting and instructive addresses on astronomical matters ever delivered in the city. Some very beautiful photos of the different heavenly bodies were shown, the mountains of the moon, taken with the huge forty-inch Yerkes' telescope, being especially interesting, as were also those of the Milky Way. Mr. Jenkins thoroughly understands his subject, and described it in a way very pleasing to his audience. A hearty vote of thanks, moved by Principal Davison, and seconded by Col. A. H. Macdonald, was accorded to the lecturer at the conclusion of the address.

J. T. L.

NOTES FROM THE METEOROLOGICAL SERVICE

Summary Report of the Weather in Canada

April

Temperature.—In British Columbia, temperatures for April did not differ much from average, the general departure being 1° below normal, although in the Queen Charlotte Islands the departure was 4° below. In the Prairie Provinces there was a general positive departure of from 2° to 4°, except in Saskatchewan, along the Southern Saskatchewan River, where the normal was exceeded by only about 1°. In northern Ontario, the departure from normal ranged from almost 0° in the Rainy River District, to about 3° below in Algoma and Nipissing Districts, and over the greater part of the peninsula of Ontario there was a negative departure amounting to from 2° to 4°, although in the Lake Erie counties the difference from normal was slight. In the western portions of Quebec, the mean for the month fell about 2° below normal, while in eastern and northern districts of the province the negative departure was about 4°. In New Brunswick, temperatures were for the most part about 2° below average, but in Nova Scotia and Prince Edward Island there was little departure.

Precipitation.—In Vancouver Island and on the Lower Fraser River rain fell on an average of about fifteen days during April. Except on the northern coast of the province and on the North Columbia River the rainfall for the month was above normal. In Alberta and Manitoba the normal was well exceed-

ed. In Saskatchewan, however, the amount of rain was considerably below normal. In Ontario the amount of rain was well above average, except locally in the Georgian Bay counties. In western Quebec there was a positive departure of about one-third, while in the eastern portion of the province there was about an equal negative departure. In the Maritime Provinces, with few exceptions, there was a marked deficiency.

May

Temperature. — In the southern interior of British Columbia, temperatures for May were mostly from 1° to 2° above the normal, while in the extreme southwest of the province and on southern Vancouver Island there was a positive departure of from 2° to 3°. Over the greater part of Alberta there was an excess of from 1° to 2°, but in the vicinity of Medicine Hat there was a negative departure of nearly 4°. In most portions of Saskatchewan, temperatures were about 1° below the normal for the month, while in Manitaba the normal was exceeded by from 1° to 2°. Over most of the peninsula of Ontario there was a positive departure of from 1° to 2°, while in the Ottawa Valley and in Northern Ontario temperatures varied from normal to 1° below normal. In the Province of Quebec and over the greater part of the Maritime Provinces temperatures for the month showed a positive departure of only 1° or a little over, but in the northeastern portions of New Brunswick and Nova Scotia positive departures were recorded of 2° and 3° respectively.

Precipitation. — Throughout the greater part of British Columbia there was a deficiency in precipitation during May, amounting to from 30 per cent. to 60 per cent. of the normal. On southern Vancouver Island, however, the normal was exceeded. In southern Alberta the rainfall was from 10 per cent. to 60 per cent. below average, while in the northern part of the province there was an excess. In Saskatchewan and Manitoba, except locally, precipitation was from 65 per cent. to 100 per cent. greater than the average for the month. Over the

greater part of the peninsula of Ontario, the rainfall was 100 per cent. and over, in excess of the normal, and at some points an excess of 200 per cent. or more was recorded. In the northern portions of the province, the excess amounted to from 40 per cent. to 60 per cent. In the northern districts of Quebec, and in Gaspé Peninsula, there was a deficient rainfall, but throughout the rest of the province there was an excess amounting to from 100 per cent. to 160 per cent of the normal. In New Brunswick, except in the central districts, the rainfall exceeded the average by from 100 per cent. to 140 per cent., and in Nova Scotia there was a considerable excess except in the eastern districts, where a shortage was recorded. In Prince Edward Island the rainfall differed little from normal.

Temperatures for April and May, 1912

Station	April		May	
	Highest	Lowest	Highest	Lowest
Yukon				
Dawson	55	00		
British Columbia				
Atlin	54	8	72	27
Agassiz	63	29		
Barkerville	54	4	74	26
Kamloops	68	26	88	39
New Westminster	62	28		
Prince Rupert	61	30	85	34
Vancouver	62	31	81	36
Victoria	60	30	84	38
Western Provinces				
Battleford	70	20	87	30
Broadview				
Calgary	65	14	82	28
Carman				
Edmonton	69	23	86	29
Medicine Hat			88	27
Minnedosa	67	14	82	21
Moose Jaw	72	13	85	27
Oakbank	72	13	82	29
Portage la Prairie	74	15	86	28
Prince Albert	64	16	86	28
Qu'Appelle	68	17	79	28
Regina	67	14	82	25
Swift Current	70	20	85	30
Winnipeg	75	18	85	26
Ontario				
Agincourt	65	17	83	29
Aurora	71	14	81	27
Bancroft	68	5	81	25
Barrie				
Beatrice	66	4	75	26
Birnam	70	22	82	32
Bloomfield	69	17	78	33
Brantford	75	22	82	31
Bruce Mines	59	- 2	76	29
Chatham	73	22		
Clinton	70	14	81	28
Cottam	75	18	85	28
Gravenhurst	67	4	80	24
Guelph	70	17	76	30
Haliburton	67	1	84	24
Hamilton	74	23	85	32
Huntsville	69	0	81	28
Kenora	60	15		
Kinmount			78	28
Kingston	64	17	73	38
Lakefield				
London	74	20	84	30
Lucknow	70	8	78	27
Madoc	68	11	80	29
Midland				
North Gower		5		
Otonabee				
Ottawa	66	9	80	34
Owen Sound				
Paris	75	21	79	32
Parry Sound	68	7	77	28
Peterboro'	76	10	80	31
Port Arthur	56	10	74	26
Port Burwell	63	22	75	31
Port Dover	65	23	77	32
Port Stanley	62	26	79	32
Ronville	68	3	77	26
Sarnia	70	22	82	34
Southampton	71	15	82	30
Stonecliffe	69	7	79	24
Stony Creek	74	24	84	33
Stratford	70	14	76	29
Toronto	71	19	82	32
Uxbridge	69	13	82	30
Wallaceburg	76	22		
Welland	76	22	82	32
White River	62	16		
Quebec				
Brome	65	6	82	24
Father Point	58	13	70	26
Montreal	63	14	84	30
Quebec	63	6	81	31
Sherbrooke	68	10	85	28
Maritime Provinces				
Charlottetown	56	11	75	27
Chatham	64	10	84	26
Dalhousie	48	5	83	22
Fredericton	65	7	83	28
Halifax	67	20	80	29
Moncton	70	11	83	24
St. John	56	17	68	34
St. Stephen			83	26
Sussex			80	25
Sydney	60	14	78	25
Yarmouth	55	19	65	30

Earthquake Records by the Milne Seismograph

TORONTO

R. F. Stupart, Director.

P. T. = Preliminary Tremors. L.W. = Large Waves. Time is Greenwich Civil Mean Time, 0 or 24 h = midnight.

No.	Date 1912	P.T Comm.	L.W. Comm.	Max.	End.	Max. Amp.	Durat.	Remarks
		h m	h m	h m	h m	mm.	h m	
1084	Apr. 3	21 58·2			22 45·5	0·1	0 47·3	
1085	" 13	19 8·1		19 8·9	19 12·4	0·4	0 4·3	
1086	" 14	No P.T's	13 54·3	13 54·8	14 10·8	0·4	0 16·5	
1087	" 17	4 2·7	4 10·5	4 14·2	4 58·1	1·0	0 55·4	
1088	" 20	2 27 82) 34·2)			2 52·7	0·05	0 24·9	
1089	May 6 or Iw.	19 13·7 19 16·8	19 20·5) 21·9)	19 24·3	21 11·9	8·5	1 58·2	Double Max. Eq. off Canary Islands.
1090	" 11	5 34·7			5 36·4	0·1	0 1·7	Being seismic
1091	" 18	22 19·8			22 20·5	0·05	0 0·7	Doubtful as to
1092	" 21	10 16·0) 10 20·1)	V_2 10 23·8	10 26·3	10 57·6	0·4	0 37·5	No defined Max.
1093	" 23	2 52·0) 2 54·0)	V_2 3 0·4 Lw. 3 16·3	3 36·8) 3 37·8) 3 41·0) 3 42·1)	5 20·0	4·5) 4·9) 3·9) 5·5)	2 28·0	Four well defined Maximums. and Hamilton felt in Toronto
1094	" 27	12 52·0			12 52·8	0·2	0 0·8	Minute jog eq.
1095	" 27	13 0·7			13 5·8	0·05	0 5·1	Uniform thickening
1096	" 28	13 13·6			14 6·3	0·1	0 52·7	

Period 14·7 seconds. 1 mm. = 0″·64.

VICTORIA, B. C.

E. B. Reed, Superintendent.

No.	Date 1912	P.T. Comm.	L.W. Comm	Max.	End	Max. Amp.	Durat.	Remarks
		h m	h m	h m	h m	mm.	h m	
1098	Apr. 3	21 48·5	V_2 21 54·1	21 57·6) 22 01·1)	22 33·1	0·8	0 44·6	No decided (max.
1099	" 3	23 01·1			23 03·1	0·1	0 2·0	(fore max. (until just be-
1100	" 14	13 (No P.T's)	13 33·4	13 35·4	13 56·3	1·0	0 22·9	Grad. thick'g
1101	" 17	4 9·2			4 54·2	0·1	0 45·0	Prolonged
1102	" 20	2 15·5			2 39·5	0·05	0 24·0	(th.ckening
1103	May 6	19 16·0 V_2 19 20·5	L.W. V_2 19 23·4) lw 19 26·8) B 19 27·5)	19 29·3 C_2 19 32·5	21 02·0	6·8	1 46·0	Second max. (well marked, (Eq. off Canary Islands
1104	" 11	5 35·0		5 36·5	5 41·6	0·5	0 6·6	
1105	" 15	0 27·0			0 34·2	0·3	0 7·2	Being seismic
1106	" 18	22 28·8			22 31·3	0·05	0 2·5	Doubtful as to
1107	" 21	10 1·1	10 5·3	10 11·1	10 36·5	0·3	0 35·4	Inc. of thickg
1108	" 23	2 43·8) V_2 2 50·5)	3 11·2 3 17·3	3 26·9 3 28·9	5 16·6	2·7 2·9	2 37·6	at 10h. 18m·4 Phases well marked.
1109	" 28	13 5·3		13 6·1	13 15·0	0·05	0 9·7	Double max.
1110	" 28	13 8·9		13 33·9	14 08·0	0·2	0 49·1	Double max.

Period 15 seconds. 1 mm. = 0″·76

J. Y.

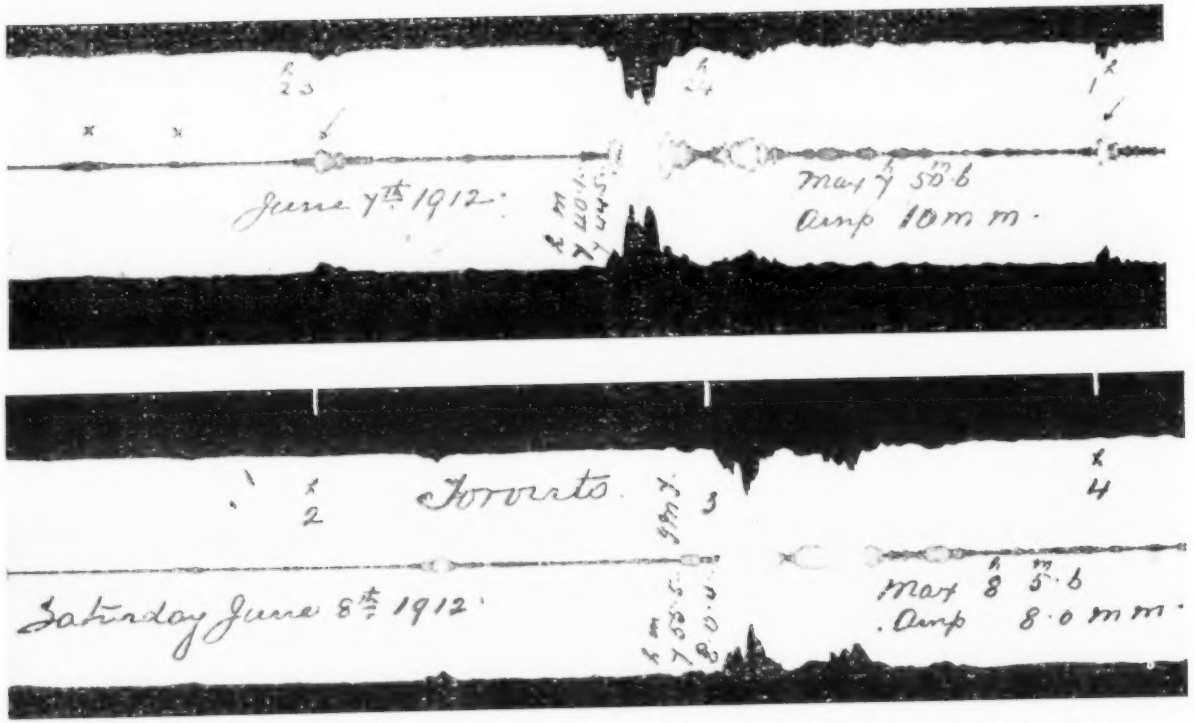


FIGURE 1.—Records with Milne Seismographs at Victoria, B.C., and Toronto, Ont. Upper record, Victoria: lower, Toronto. Figures 1, 2, 3 give the record of a number of Alaskan earthquakes on June 8th, 1912. The time shown at the top of the record is Standard Time, Toronto being 5h. ahead of Victoria. The Greenwich Mean Time is written in beside the record of the quake.

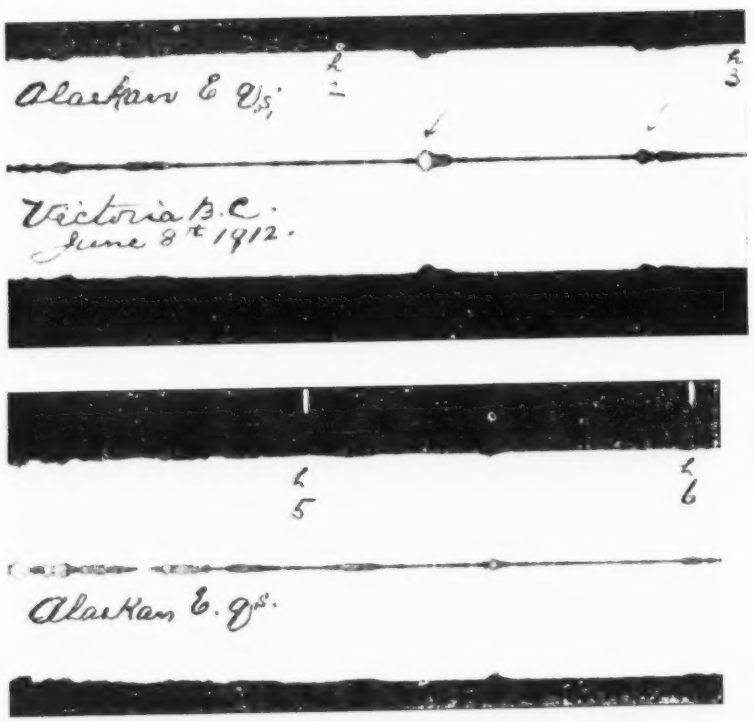


FIGURE 2.

Records with the Milne Seismographs at Victoria, B.C., and Toronto, Ont. Upper record, Victoria; lower, Toronto. (See under Figure 1).

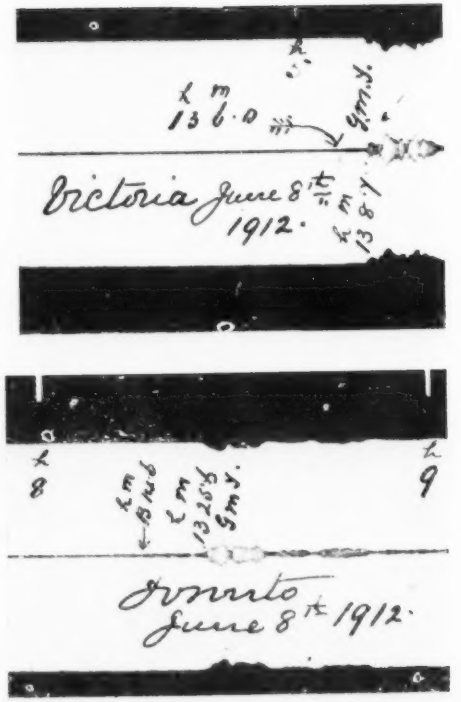


FIGURE 3.

MAGNETIC OBSERVATIONS

With the exception of small disturbance from 22 o'clock of 11th to 5 o'clock of 12th of May the magnets were quiet.

Declination

Month	Mean of Month	Max.	Date	Min.	Date	Monthly Range	Amplitudes—Mean Daily: From hourly readings	Amplitudes—Mean Daily: From Means of Extremes
1912	° ′	° ′		° ′		° ′	′	′
Apr.	6 13·0	6 30·3	10 7 16 3	5 54·4	14	0 35·9	10·2	13·7
May	6 13·3	6 34·6	12	5 39·7	12	0 54·9	11·3	15·7

Bifilar—C.G.S. Units

Apr.	·16184	·16213	9	·16048	15	·00165	·00032	·00052
May	·16186	·16230	13	·16114	12	·00116	·00042	·00053

Inclination

Month	Mean Dover No. 200	Mean Earth Inductor
	° ′	° ′
April	74 39·4	
May	74 39·0	

ASTRONOMICAL NOTES

A Note on Gelatine used in the making of Light-Filters. — The following note taken from a recent issue of "Photographische Rundschau" is given in the *British Journal of Photography* for March 15, 1912. Baron A von Hübl draws attention to the irregularity which may be caused in the making of dye light-filters as a result of impurities in the gelatine used as vehicle. He recommends the use of iodine as a destroyer of these impurities.

In the preparation of light-filters for photographic work it is now almost the universal practice to employ glass plates coated with a solution of gelatine containing dissolved aniline dyes. In doing this it is generally assumed that the gelatine is a perfectly inert body, simply playing the part of the vehicle of the dye. The assumption cannot, however, always be made, since gelatine frequently contains certain impurities which even when existing only in traces may yet give rise to quite notable changes in the dyes. These irregularities are most likely to be felt in the case of the deeper filters, such as the dark yellow light-filters, or the highly selective filters employed in three-color work, as also in the compensating filters used for the Autochrome plate.

A radical means of rendering such a gelatine serviceable for preparation of filters consists in addition, before incorporating the dyes with the gelatine solution, of a little iodine tincture — about ·5 to 1 cc. of 1:100 iodine solution — to 10 gms of dyed gelatine. This proportion of iodine is amply sufficient as a rule :

in certian cases it may perhaps be not quite enough, and it is, therefore, well to test the gelatine solution before use as regards its effect on the dyes. For this purpose the test portion is stained as above described with "echt-rot," the solution flowed on to a glass plate and put to dry. If the film is of clear rose-red color the use of the gelatine may be proceeded with but if on the other hand, the dry film shows a brownish-yellow color, a further slight addition of iodine tincture should be made and the test repeated.

As regards the preparation of filters with very strict absorptive qualities the results are extremely uncertain when working with the gelatines ordinarily found in commerce. For example, an Autochrome filter prepared with filter-yellow and "echt-rot" may turn out to be brownish-yellow instead of orange, and, using for such filters the dyes filter-yellow and kristal-ponceau, etc., a red color of very different character is obtained, in spite of the most scrupulous precautions and adherence to the formula, according to the quality of the gelatine.

The use of the iodine process given above may, therefore, be recommended to all : from such simple tests as those described, any one may discover whether the gelatine employed for light-filters is in any way open to suspicion for the reasons described. — *Popular Astronomy*, Vol. XX., No. 6.

The Solar Eclipse of April 17.— Dr. W. J. S. Lockyer was stationed as nearly as possible on the line predicted by the American Ephemeris, about three quarters of a mile north-east of the village of Chavenay. Several prominences were observed, and from the symmetrical appearance of Baily's beads it was concluded that the eclipse was quite central. From various papers in the Comptes Rendus for April 22 we learn that a little before second contact M. Bigourdan believed he saw the exterior edge of the dark moon projected against the lower corona or upper chromosphere. It appears certain that nowhere in Europe was the eclipse definitely total. M. Salet reports that in Portugal Baily's beads were seen round the Moon through the whole of the maximum phase. He places the central line

south of that given by the American Ephemeris halfway towards that given by the Connaissance des Temps. Students from the École Polytechnique were stationed in pairs along a line 12 km. in length across the eclipse track between Trappes and Neauphle at intervals of one hectometre. Their results place the central line between those of the Connaissance des Temps and the American Ephemeris 500 m. from the former and 2400 m. from the latter. They found the diameter of the moon between the valleys 1″·2 less than that of the sun, whilst the diameter including lunar peaks was 0″·8 greater. At Lyons Observatory 6000 kinematograph pictures were made of a screen on which images of the sun and moon were projected and on which a carefully rated watch was also hung. The average rate was ten photographs per second.—*Journal British Astronomical Association* for May.

The Great Telescope for the Allegheny Observatory.—The 30-inch refracting telescope for the Allegheny Observatory is practically finished except the lenses, which are to be ground and polished at the optical works of Dr. John A. Brashear and are expected to be finished in about nine months.

Everything about the telescope is made of iron, so that all expansion due to heat and cold will be the same, and not throw the mechanism out of adjustment. Necessarily no heat may be admitted to the dome, and during the long 14-hour winter nights, which are best for observations because of the clearness of the atmosphere, the observer must sit in the cold, surrounded by iron which would freeze him fast were he to touch his bare hand to it. Dr. Schlesinger says that he has spent nights in domes where the thermometer stood at 28° below zero, and he has an Eskimo costume, such as is used by arctic explorers, for that purpose.

The telescope has been in process of construction for 10 years. It is the gift of the Thaw family, to the memory of William Thaw, and cost more than $100,000.—*Popular Astronomy* for May.

MAGNETIC POWER OF THE EARTH.— Professor Arthur Schuster, says the *Athenæum*, has lately made a serious attempt to solve the problem of the magnetic power of the earth, and has examined carefully all the current theories on the subject. The fact that the magnetic poles are only a few degrees distant from the true poles of the earth has led many to conclude that the rotation of the earth on its axis must in some way be accountable for the phenomenon; but Professor Schuster gives several reasons for thinking that this reasoning is wrong. He is more inclined to the theory that the earth is a magnet because of the masses of iron concealed within her crust, and thinks that this has not been sufficiently investigated. The laws of magnetism as exhibited on the surface may, he says, be entirely different at the high temperature and enormous pressure which are supposed to exist in the interior of the earth, and this is the direction in which further experiment may be useful.—*English Mechanic and World of Science*, May 31, 1912.

VALUE OF SCIENTIFIC RESEARCH.— In *Popular Science Monthly* for May, Professor R. A. Millikan, of the University of Chicago, puts very tersely and effectively the answer to those who find fault with the spending of large sums of money for scientific research.

"But," says some one, "What of it anyway? Does the triumph or defeat of the kinetic theory of matter or the atomic theory of electricity have anything to do with the *practical* problems of the modern world? Is anybody going to be better fed or better clothed because of it?"

The answer is "Within the past seventy-five years — the merest drop in the bucket of recorded time — the conditions of human life on this earth have been completely revolutionized, and that solely because, for the first time in history, man has become interested in considerable numbers, rather than as heretofore in isolated instances, in patiently and persistently seeking merely to uncover nature's 'useless' secrets, and then, when the inner workings have been laid bare, has in many cases seen a way to put his brain inside the machine and drive it where he

would. Every increase then in man's knowledge of the way in which nature works must in the long run increase by just so much man's ability to control nature and to turn her hidden forces to his own account."

As a result of his computations Professor Millikan finds that "there are in a cubic centimetre of gas under normal conditions $2{\cdot}70 \times 10^{19}$ molecules, and the weight of a hydrogen atom is $1{\cdot}735 \times 10^{-24}$ grams. These numbers can be made more significant to the ordinary reader with the aid of an illustration. If a million men were to be set counting as fast as they could count, say at the rate of 200 a minute, they could count out the number of molecules in a cubic centimetre in just 252 thousand years, if none of them ever stopped to eat, sleep, or die."—*Popular Astronomy*, Vol. XX., No. 6.

Convergent Stars.— The most remarkable group of stars with a well-determined convergent is that in Taurus, discovered by Professor Lewis Boss in 1908. The group occupies an area about 18° in diameter, with the familiar V-shaped cluster known as the Hyades near its centre. The first magnitude red star Aldebaran does not partake of the common movement, but all the other prominent stars of the Hyades are moving together toward a point about 30° east and 8° south of the star γ, the star at the bottom of the *V*. Professor Boss found 41 stars whose proper motions converge to very nearly the same point, within the limits of probable error of the data in most cases. He found the position of the convergent to be for 1875:

R. A. $6^h\,7^m{\cdot}2$; Decl. + 6° 56′.

—*Popular Astronomy*, Vol. XX., No. 6.

J. R. C.

NOTES AND QUERIES

Communications are Invited, Especially from Amateurs. The Editor will try to Secure Answers to Queries.

THE QUESTION OF KEEPING TIME

Our present method of counting time is so simple in practice, and our time-pieces are so cheap and so good that we seldom give a thought to the unsatisfactory conditions which formerly existed. This matter, however, was brought to the writer's attention a short time ago on being shown, by a colleague, the original announcement, in the hand-writing of Sir Daniel Wilson, the former President of the University of Toronto, of the introduction of standard time in 1883. A fac-simile of this is reproduced herewith (next page).

Until about the year 1816 the clocks of Paris were regulated according to apparent time, that is, according to the passages of the true or real sun across the meridian. On account of the lack of uniformity in the sun's apparent motion amongst the stars, (due to the earth's revolution about the sun) the intervals between successive passages of the true sun are of varying length, and so when apparent time was used it was necessary to modify the rate of going of the clocks every day or at least every week. Now they are regulated by the movement of a mean or fictitious sun, which has a uniform motion amongst the stars, and which is sometimes ahead and sometimes behind the true sun.

Arago says that Delambre (1749-1822) told him that he had heard the same hour struck in Paris by different clocks through a whole half-hour. The introduction of mean time at once brought order out of such chaos, and led to great improvement

The President invites the attention of the Professors & Lecturers to the introduction of Standard Time, 17 minutes in advance of Solar Time, which will be adopted in the College, Commencing on Monday next. the 19th Inst.

Univ. Coll.
16th Nov. 1883.

THE ANNOUNCEMENT BY PRESIDENT DANIEL WILSON.
Posted in the University of Toronto, stating that Standard Time would be adopted.
(Facsimile from the original in possession of Professor W. J. Loudon).

in the construction of time-pieces, but with the growth of our transportation systems complications again arose.

For the satisfactory running of trains on any railway line the clocks must all show the same time, and, of course, the question arises as to the time of what place they are to be regulated by. In a letter to the Editor, Professor Cleveland Abbe, the well-known officer of the United States Weather Bureau, states that in October, 1859, he found six standards of time in use in the railroad station at Utica and from that time onward he was persistently agitated for a reform. In *Science* for September 8, 1905, Professor Abbe gave an account of the introduction of Standard Time in America.

The study of meteorological phenomena, in which the reports must be reduced to some common time, and the transmission of time signals over large portions of the country, as well as the handling of railway trains, showed the desirability of having some uniform time. In May, 1875, Professor Abbe requested the President of the American Metrological Society (F. A. P. Barnard, President of Columbia University) to bring the matter of time reform before that society. A committee was at once appointed with Professor Abbe as chairman. Reports were published in successive years, and numerous articles were published in the newspapers and magazines urging the adoption of a new system. In May, 1879, the full report of the committee was published. In it the existing state of confusion was set forth and a simple practical system of standard meridians at hour intervals form Greenwich was outlined. The publication of this report brought out the fact that others were thinking along similar lines, among them Professor C. F. Dowd, Sanford Fleming and W. F. Allen, Secretary of the General Time Convention of Railroad Officials.

The proposals were adopted by the Chief Signal Officer, by various astronomers and others, and as a result the railroads agreed that the standard hour system should go into effect on November 18, 1883. As we all know the system has worked admirably.

In our north-west provinces the railroads use the 24-hour system instead of A.M. and P.M. Perhaps when they become thickly populated this notation may be introduced into every part of Canada.

EQUIPMENT OF THE METEOROLOGICAL OBSERVATORY IN 1853

In the last number of the JOURNAL, Director Stupart gave an historical account of the growth of the Canadian Meteorological Service, including, of course, the observatory at the Headquarters in Toronto. The present writer has come across an interesting relic of early days when Professor J. B. Cherriman was in charge. It consists of a sheet of paper containing, in the handwriting of Professor Cherriman, a list of "Instruments in use at the Obsevatory." The original belongs to Professor W. J. Loudon, who has allowed a facsimile to be made of it which is reproduced herewith. (Page 220).

It is interesting to compare the instrument, in use in 1853 with those in 1912. Almost every meteorological element is now recorded continuously, an efficient time-service is maintained, there is an elaborate outfit for producing the daily weather map, and physical researches are also carried on.

ROTATION PERIOD OF URANUS

At the meeting of the Royal Astronomical Society on May 10, Professor Percival Lowell announced the discovery of the rotation period of Uranus. It was obtained by means of spectrograms taken at the Lowell Obsevatory, Flagstaff, Arizona, and was found to be 10¾ hours, very similar to the periods of Jupiter and Saturn.

Instruments in use at the Observatory

April 11th. 1853

1 Meantime Clock — With Mercurial Pend.m to ½ seconds by Beat

2. Universal Instrument

3. Transit Inst.t — 2 Eye-pieces, & 3 Sun glasses, with Level

4. Daguerreotype Apparatus — Camera Obscura; 2 boxes for Silver plates; Mercurial Bath and Lamp; buff;

5. Three 1 foot-Scales
One 2 foot-Scale
1 Parallel Ruler
1 4-foot Scale.
Mounted.

6. Box of Drawing Inst.s. — With 3 ivory scales, wanting 1 pair compasses.

J.B.L.

7 One Maximum Register Thermometer } By Watkins and Hill.

FACSIMILE OF A LIST OF INSTRUMENTS

At the Meteorological Observatory, Toronto, in 1853, in the handwriting of Director Cherriman.

(Original in possession of Professor W. J. Loudon).

SUMMER PHILOSOPHY

CHARACTERS:—The Marchioness of G———, The Philosopher.
TIME AND PLACE:—10 p.m. on a summer evening; in the park.

One evening, after supper, we went to take a turn in the park; the air, from the heat of the preceding day, was extremely refreshing; the moon about an hour high, and her lustre between the trees, made a most agreeable mixture of light and shade; the stars were arrayed in all their glory, and not a cloud appeared throughout the hemisphere. I was musing on this awful prospect — but who can long contemplate on the moon or stars in the company of a pretty woman? I am much mistaken if that is a time for contemplation: well, madam, says I, to the marchioness, is not the night as pleasant as the day? The day, replied she, like a fair beauty, is clear and dazzling; but the night, like a brown one, more soft and moving. You are generous, madam, answered I, to prefer the brown, who have all the charms that belong to the fair; but, is there anything more beautiful in nature than the day? the heroines of romances are generally fair; and that beauty must be perfect, which has all the advantages of imagination. Tell me not, says she, of perfect beauty; nothing can be so that is not moving. But since you talk of romances, why do lovers in their songs and elegies address themselves to the night? It is the night, madam, replied I, that crowns their joys, and, therefore, deserves their thanks. But it is the night, answered she, that hears their complaints, and how comes it to pass, the day is so little trusted with their secrets? I confess, madam, says I, the night has somewhat a more melancholy air than the day; we fancy the stars march more silently than the sun, and our thoughts wander with the more liberty, whilst we think all the world at rest but ourselves: besides, the day is more uniform; we see nothing but the sun, and one light in the firmament; whilst the night shows us variety of objects, and gives us ten thousand stars, which inspire us with as many pleasant ideas. She replied, what you say is true; I love the stars; there is something charming in them, I could almost be

angry with the sun for effacing them. And I cannot, says I, pardon him, for keeping all those worlds from my sight. What worlds, says she, looking earnestly upon me, do you mean?

I beg your pardon, madam, replied I, you have put me upon my folly, and I begin to rave. What folly? answered she, I discover none. Alas, says I, I am ashamed, I must own it, I have had a strong fancy that every star is a world: I will not swear that it is true, but must think so, because it is so pleasant to believe it; it is a fancy come into my head, which is very diverting. If your folly be so diverting, says the marchioness, pray make me sensible of it; provided the pleasure be so great, I will believe as much of the stars as you would have me. I fear, madam, replied I, it is a diversion you will not relish; it is not like reading one of Molière's plays; it is a pleasure rather of the fancy than of the judgment. I hope, answered she, you do not think me incapable of it; teach me your stars, I will show you the contrary. No, no, says I, it shall never be said that I was talking philosophically at ten o'clock at night, to the most amiable creature in the universe; find your philosophers somewhere else.

But vain were my excuses; who could resist such charms? I was forced to yield, and yet I know not where to begin; for to a person who understands not anything of natural philosophy, you must go a great way about to prove that the earth may be a planet; the planets so many earths; and all the stars distinct worlds; however, to give her a general notion of philosophy, at last I resolved on this method. Madam, says I, all philosophy is founded on these two propositions:

1. That we are too short-sighted.
2. That we are too curious.

For if our eyes were better than they are, we should soon see whether the stars were worlds or not; and if, on the other hand, we were less curious, we should not care whether the stars are worlds or not, which I think is much to the same purpose. But the business is, we have a mind to know more than we see; and again, if we could discern well what we do see, it would be too

much known to us; but we see things quite otherwise than they are. So that your true philosopher will not believe what he does see, and is always conjecturing at what he doth not; which I think is a life not to be envied: upon this I fancy to myself, that nature very much resembles an opera; where you stand, you do not see the stage as it really is, but as it is placed with advantage, and all the wheels and movements hid, to make the representation the more agreeable: nor do you trouble yourself how, or by what means the machines are moved, though certainly an engineer in the pit is affected with what does not touch you; he is pleased with the motion, and is demonstrating to himself on what it depends, and how it comes to pass. This engineer is like a philosopher, though the difficulty be greater on the philosopher's part, the machines of the theatre not being near so curious as those of nature, who disposes her wheels and springs so much out of sight, that we have been a long while guessing at the movement of the universe. . . . . .

I perceive, says the lady, philosophy is now become very mechanical. Yes, madam, replied I, so mechanical, that I fear we shall quickly be ashamed of it; they will have the world to be in large, what a watch is in small, that is very regular, and depends only upon the just disposition of the several parts of the movement. But pray tell me, madam, had you not formerly a more sublime idea of the universe? Do not you think then that you honoured it more than it deserved? for most people have the less esteem for it, since they have pretended to know it. I am not of their opinion, says she; I value it the more since I know it resembles a watch; and the more plain and easy the whole order of nature seems, to me it appears the more admirable.

I do not know, answered I, who has inspired you with these solid notions, but I am certain there are few who have them besides yourself: people generally admire what they do not comprehend; they have a veneration for obscurity, and look upon nature, as a kind of magic, while they do not understand her; and despise her below legerdemain, when once they are acquainted with her; but I find you, madam, so much better

disposed, that I have nothing to do but to draw the curtain, and show you the world.

That noble expanse which appears farthest from the earth, where we reside, is called the heavens, that azure firmament, where the stars are fastened like so many nails, and are called fixed, because they seem to have no other motion than that of their horizon, which carries them with itself from east to west. Between the earth and this great vault, as I may call it, hang, at different heights, the sun, the moon, with the other five stars, Mercury, Venus, Mars, Jupiter and Saturn, which we call the planets. These planets, not being fastened to the same heaven, and having very unequal motions, have diverse aspects and positions; whereas the fixed stars, in respect to one another, are always in the same situation: for example, the Chariot, which you see is composed of these seven stars, has been, and ever will be as it now is, though the moon is sometimes nearer to the sun, and sometimes farther from it; and so it is with the rest of the planets. Thus, things appeared to the old Chaldean shepherds, whose great leisure produced these first observations, which have since been the foundation of astronomy; which science had its birth in Chaldea, as geometry sprung from Egypt, where the inundation of the Nile, confounding the bounds of the field, occasioned their inventing more exact measures to distinguish every one's land from that of his neighbor. So that astronomy was the daughter of idleness, geometry the daughter of interest; and if we did but examine poetry, we should certainly find her the daughter of love. — (From Fontenelle's "Plurality of Worlds," published in 1686).

ROBERT RIDGWAY: A CORRECTION

In the last number (page 150) it was stated that Mr. Ridgway was born in 1843. This should have been 1823, as at his death he was in his 89th year. When he first became a member of the Astronomical Society he was a teacher in the "Grammar" School on Jarvis St.

C. A. C.